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LETTER OF TRANSMITTAL

To his Excellency

THEODORE ROOSEVELT *Governor of the State of New York*

SIR: During the year beginning October 1897 active investigation of the geology of the state has progressed under the provision made by the legislature for the completion of the geologic map.

In the crystalline region of the Adirondack mountains Professors J. F. Kemp, H. P. Cushing and C. H. Smyth jr have continued and brought to virtual conclusion the survey of this district, as contemplated in the original plan for this work. These gentlemen have brought to bear on a difficult region that abounds in perplexing problems, an intimate acquaintance with the geology of the crystalline rocks, and the result of their work, pursued now through several successive seasons, will permit the coloring of this area on the map with much greater exactitude and detail than has before been possible. Their reports are herewith appended; that of Prof. Kemp covering Hamilton, Warren and Washington counties, Prof. Cushing's observations pertaining specially to Franklin county, while Prof. Smyth gives concisely the results obtained by him in the mapping of the western part of the Adirondack region.

To complete the coloration of the areas of the Jura-trias, or Newark sandstone strata of the state, Dr Henry B. Kümmel, of the geologic survey of New Jersey, was employed. In his work for the state of New Jersey Dr Kümmel had given special attention to the structure and distribution of these strata, and was specially fitted to carry his observations over the line to the very limited area covered by them in Rockland county (N. Y.) A carefully prepared report on the geology of this formation, with a map showing the distribution of the sandstone rocks and accompanying volcanic masses, is herewith transmitted.

The relations of the important series of waterlime beds of western and central New York to the strata above and below them were made the subject of special investigation by D. D. Luther, who executed a series of sections across this formation from Erie county through Genesee, Livingston, Ontario, Seneca, Cayuga and Onondaga counties. The result of this work has afforded important and accurate information with regard to the distribution of these beds and the character and variation of their fossil contents, and the same sections have been made to embrace the overlying Oriskany sandstone and its variations.

Work has been carried forward in the investigation of the fossil faunas of the Portage rocks in Erie and Chautauqua counties by the assistant paleontologist aided by Mr. Luther. This work included observations made from a considerable number of outcrops, with collections of material embracing species of fossils not before represented in the collections of the state museum. Later in the season material was gathered for the preparation of a revised geologic map of Ontario county, and this was in continuation at the opening of the succeeding year. The results of it will be plotted on the topographic sheets of that county as soon as they are available for this purpose.

Some work was also done in the central part of the state north of the Mohawk valley in following the outcrops and contacts of the Oswego and Medina sandstones, by C. J. Sarle.

In the office the coloration of the state map was carried forward with the acquisition of new results from the field. In paleontologic investigations the final touches were given to the memoir on the Dictyospongidae which was in press for most of the year. Work on the generic characters of the fossil corals, preparatory to a memoir on this subject, also progressed, and a considerable number of drawings representing these fossils were made by George B. Simpson. The time of the assistant paleontologist has been largely absorbed by the duties of the office and the attention required by the printing of the annual reports, but his investigations of the Oriskany fauna of Becraft mountain and of the composition and character of the Portage fauna of western

New York have advanced, the first nearly to completion. It is planned to present as early as practicable a comprehensive report on the stratigraphy and paleontology of the Portage formations.

With this report is communicated, in addition to the papers specified above, some observations by Prof. C. S. Prosser, of Union university, on the succession of the formations in the Helderberg mountain region. Though this is classical ground for the geologist, yet no carefully detailed and accurate sections available to the general student have heretofore been published.

On Aug. 7, 1898, occurred the death of James Hall M. D. LL. D., the venerable head of this department, in his 87th year. Prof. Hall had been in his usual health throughout the year, and so far as was known had felt no foreboding of the coming end. He had left Albany, as was his annual custom, to escape the summer heat, and the end came to him at Echo hill, near Bethlehem (N. H.) It is impossible in this place adequately to express the loss which this department and the state of New York suffer by his death. Prof. Hall had been in the service of the state since 1836, first having been assistant to one of the original state geologists and since 1837 state geologist of New York, a period of public service extending over 62 years; a record probably unapproached in the annals of the civil service of this state. With a more suitable occasion a memorial of Prof. Hall's public career and service to geologic science will be issued.

Very respectfully

JOHN M. CLARKE

Acting state geologist and paleontologist

THE NEWARK OR NEW RED SANDSTONE ROCKS OF ROCKLAND COUNTY, N. Y.

HENRY B. KÜMMEL Ph.D.

CONTENTS

The Palisades ridge near Haverstraw, from the south. High Tor

Plate 1

ON THE LEFT, SHORT CLOVE IN THE CENTER AND LONG CLOVE ON THE RIGHT

NEWARK ROCKS OF ROCKLAND COUNTY, N. Y.

The Newark formation occurs in New York state only in Rockland county. It occupies a triangular area the base of which is formed by the New Jersey state line between Suffern and the Hudson river, and the apex of which is at Stonypoint. The Hudson river marks one side of the triangle, and the steep escarpment of Ramapo mountain, stretching northeastward from Suffern to Stonypoint, forms the other. The area of the triangle is about 100 square miles.

This small area is the northern end of a belt which extends southwest through New Jersey, Pennsylvania, Maryland and into Virginia. It must therefore be studied with due regard for this relationship and in the light of conclusions drawn from the careful examination of the more southern parts of the belt.[1] Some of the conclusions set forth in this paper have been based on evidence collected in New Jersey, and would not be warranted were the facts of this smaller area only to be considered.

TOPOGRAPHY

The region is characterized by a rolling topography—a series of hills trending north and south, separated by valleys which have been eroded from 150 to 200 feet below the level of the hilltops. There is usually but slight difference in the steepness of the eastern and western slopes of these ridges, although where such a difference exists, the eastern slope is nearly always the steeper. Most of the roads which extend north and south follow either the valleys or keep along the crests of the hills and are fairly level. The east and west roads cross the narrow, steep-sided ridges at right angles and are very hilly. The general level of the tops of the hills in the western part of the area

[1] Detailed reports on the New Jersey area will be found in the annual reports of the state geologist of New Jersey for 1896 and 1897. Trenton N. J.

is between 600 and 700 feet A. T. From this elevation it declines gently eastward to the valley of the Hackensack river, the inclosing hills of which are less than 300 feet high. A sharply marked ridge, varying in width from one half mile to 2 miles, extends along the eastern border from the state line to Haverstraw. Its hight ranges from a little over 200 feet at the south to a maximum of 832 feet at High Tor, just south of Haverstraw. With the exception of the gorge at Piermont, where it has been cut through almost to tide level by a stream which drains the back country, it is everywhere much higher than the adjacent region on the west. Within the distance mentioned, from the state line to Haverstraw, the ridge rises abruptly almost from the bank of the Hudson, except in the vicinity of Nyack, where for a distance of 3 miles it lies about three fourths of a mile back from the river and is bordered by ground having an elevation of about 200 feet. Just south of Haverstraw this ridge turns away from the river and extends westward for several miles, gradually losing its distinctness, not so much because it decreases in hight as because the adjacent country attains a higher general level. Not only is this ridge higher, wider, more massive, more sharply marked and less interrupted by gaps than any of the others, but its eastern and western slopes are more sharply contrasted. Everywhere the eastern slope is exceedingly steep, not infrequently a vertical cliff, whereas the western is generally long and comparatively gentle.

These various topographic features are dependent chiefly on the geologic structure of the region. The north and south ridges, as will be brought out in greater detail below, follow the trend of the rocks, and their existence is due to slightly harder and more resistant beds of sandstone and conglomerate. The general lower elevation of the hills in the western part of the area, bordering the Hackensack river, is to be explained by the softer character of the rocks, there more largely shales and sandstones. The massive, sharply marked ridge along the Hudson river is produced by a belt of trap, an exceedingly resistant rock, which has been intruded into the sandstones. The steeper eastern slopes are readily explained by the general westward dip of the strata.

It is a truth of wide application that the topography of any region is intimately dependent on its geologic structure; and this truth finds ready illustration within this area. In the following pages attention will be directed more than once to this relationship.

GEOLOGY

The sedimentary rocks comprise shales, sandstones and conglomerates. They are generally red in color but not always. Some of the sandstone layers are gray and brown, and occasionally black or dark green beds of shale occur, but the great mass of the formation is a dull red color, so monotonous in the unchanging succession of layer after layer that differentiation on this basis is well nigh impossible.

The character of the rocks and their relations to the larger area can best be understood by a comparison with the section along the Delaware river in New Jersey, where they are well shown. Here it is possible to divide the beds into three groups. At the base there is a succession of 1) coarse, more or less disintegrated arkose conglomerates, 2) yellow, micaceous, feldspathic sandstone, 3) brown red sandstones or freestones, and 4) soft, red argillaceous shales. These are interbedded and many times repeated, a fact which indicates rapidly changing and recurrent conditions of sedimentation. The characteristic beds of this subdivision are the arkose sandstones and conglomerates. I have used the term Stockton in connection with this group.

Overlaying the Stockton beds, there is a group of hard dark colored shales and flagstones, called the Lockatong beds. They consist of 1) carbonaceous, thin splitting shales, 2) hard, massive, black and bluish purple argillites, 3) dark gray and green flagstones, 4) dark red shales approaching a flagstone and 5) occasional thin layers of highly calcareous shale. There are all gradations between these somewhat distinct types, which are interbedded and several times repeated in varying succession. The presence of sun-cracks at all horizons shows that shallow water conditions prevailed throughout the time of their deposition, though the extreme fineness of the material indicates the absence of strong currents or violent shore action.

Above the Lockatong beds there occurs a great thickness of soft argillaceous shales and occasional sandstone layers. They are predominantly red in color, though a few purple, green, yellow and black beds are present. Ripple-marks, sun-cracks and rain-drop impressions occur at many horizons, and imprints of leaves, of tree stems, or the stems themselves are frequently found. The numerous reptile and other vertebrate tracks, which have made the Newark beds famous, occur chiefly in this subdivision. The evidence is conclusive that these beds also were deposited in shallow water.

As these groups of rocks are traced northeastward across New Jersey toward New York, certain important changes in their constitution can be noted. These are more marked in the case of the Lockatong and Brunswick groups than of the Stockton beds. The latter occur both beneath and above the trap sheet which forms the Palisades and can be seen in numerous exposures along the shore of the Hudson river. Owing to the influence of the trap sheet, the adjoining beds are generally highly metamorphosed, the most conspicuous change being an alteration to black and purple or dark green shales, quite unlike any beds in the section along the Delaware river. These changes, however, are due entirely to the alteration produced by proximity to the molten mass of the Palisade ridge at the time of its intrusion into the sedimentary beds.

The Lockatong beds do not occur in the northeastern part of the New Jersey area. Their absence is probably due to the fact that the conditions favoring the deposition of fine grained, hard carbonaceous shale and argillites did not prevail in this region. The facts so far as known apparently show that the black shales and argillites grade into and are represented by red shale and sandstone to the northeast.

The Brunswick beds, which on the Delaware river are chiefly soft, argillaceous, red shales, increase in coarseness to the northeast, so that in the region adjoining New York this group consists chiefly of sandstones and even conglomerates. Where the Brunswick beds are soft shales, the surface is a gently rolling lowland,

having an average elevation of from 100 to 200 feet above sea level. With the appearance of the coarser and more resistant beds the general elevation becomes greater, and in place of the gently rolling lowland, there is a succession of ridges and valleys following very closely the trend of the beds. The rock of all the ridges is much alike. It is a coarse sandstone with some pebble-bearing beds and occasional shale layers. The constituent pebbles are sandstone, quartzite, quartz, limestone, slate and feldspar, while there is an entire absence of granite, gneiss or schist. Occasionally pebbles 5 inches in diameter occur.

The charcteristics which were observed in the northern part of the New Jersey belt persist in New York state. Beds of the Stockton group occur beneath the trap sheet at Piermont, and probably also along the west of the Palisade ridge as far north as Blauveltville, though, owing to the heavy accumulations of glacial drift within this area, exposures are rare. Between Piermont and Nyack the trend of the rock is such as to carry them beneath the Hudson river, and the beds exposed along the shore near Nyack and farther north apparently belong to a horizon above the Stockton group.

In New York there are no beds which in lithologic characteristics compare with the Lockatong group. The hard, black shales and argillites typical of this subdivision do not occur. The conditions favorable for their accumulation evidently did not prevail in this region. There is, however, no evidence that sedimentation did not take place in the New York area while the argillites were being deposited in New Jersey and Pennsylvania. The arkose sandstones here grade upward into red shales, sandstones or conglomerates which resemble lithologically the members of the Brunswick group.

The characteristics which distinguish the Brunswick beds in Bergen county (N. J.) persist in Rockland county (N. Y.) Political boundaries are not in this case at least geologic boundaries. The description of the sandstones and conglomeratic layers given above applies equally well to Bergen county or to Rockland county. Overlying the gray arkose sandstone on either side of

the Palisades near Piermont, there is a great thickness of coarse sandstones, with some shales and some conglomerates. In general the shales and finer grained sandstones are more abundant in the eastern part of the area, i. e. lower in the series, and the conglomeratic beds increase in number and thickness in the western part. This change in lithologic constitution is reflected in the topography, for the coarser sandstones and conglomerates are more resistent than the shales and therefore form a higher belt of country. There is no sharp line of demarcation between the beds referred to the Stockton group and those considered the equivalents of the Brunswick shales.

The characteristics of these beds and the succession of layers will be better understood by a somewhat detailed statement of the outcrops as found in various parts of the area.

Local details. Arkose sandstones and red shales outcrop along the Hudson river at many points from the state line, northward to Haverstraw. With the exception of a few localities of limited extent, where the trap rock of the Palisades descends to the water's edge, the sandstone and shale everywhere underlie the trap and form the lower part of the steep escarpment which is so conspicuous a feature on the west bank of the Hudson river from Hoboken (N. J.) to Haverstraw (N. Y.)

At Piermont there are a number of good exposures of a coarse, gray arkose sandstone, which is pebble-bearing in some layers. Just below the railroad station the trap and sandstone are exposed on opposite sides of the road, and the latter can be seen to be somewhat indurated near the trap. A mile north of here there is a small exposure of hard, straw-colored sandstone and indurated, black shale in a stream bed about 10 feet below the base of the trap.

Midway between Nyack and Piermont, a line of old quarries along Piermont avenue gives good exposures of heavy bedded, red shale and fine grained, red and brownish sandstone. None of the beds were observed to be conglomeratic. These beds are slightly above those exposed at Piermont. The latter resembles the New Jersey beds which I have called Stockton and are apparently very

Plate 2

Glacial boulder on the crest of the Palisades, south of Nyack

near the top of that group. Those in the quarries and northward along the river for several miles resemble the Brunswick shales. As before noted, the black argillites (Lockatong) do not occur in this area nor the adjoining part of the New Jersey area.

From Nyack northward to Verdrietege Hook exposures of shale and fine grained sandstone are frequent. At Upper Nyack and in the beds of two small brooks which have cut deep ravines there are good opportunities for study. From Piermont northward the trap sheet recedes from the river till at Nyack it reaches a maximum distance of a mile, so that the belt of sandstone and shale east of it is correspondingly wide. But at Verdrietege Hook, two miles north of Nyack, the trap ridge by an abrupt turn reaches the river, and thence north nearly to Haverstraw, a distance of six miles, the sandstone is restricted to a narrow strip locally absent, between the water's edge and the foot of the trap cliffs which rise almost directly from the river.

In the region west of the Palisades exposures are so widely scattered, owing to the thick accumulations of drift, that anything approaching a complete section is impossible. Locally outcrops are abundant along the tops of the ridges which form such a distinguishing feature of the topography. In other localities they are clustered together along the side slope of the hills, or in some cases along the bottom of the valleys. Very commonly the transverse streams, those which have cut their valleys across the ridges or have carved deep ravines in their sides, reveal the bed rock along their channels. But it is quite uncommon to find the longitudinal streams flowing on the bare rock. Outcrops are far more abundant along the crests of the ridges than in the bottoms of the valleys, a fact which indicates that the topography of the rock surface beneath the drift is more rugged than that of the present surface. The layer of sand, gravel and stony clay, which unevenly mantles the rocks, is in general thicker in the valleys than on the tops of the ridges, and the topography, rolling as it is at present, is one of less relief than was the surface which preceded the deposition of the glacial drift.

So far as can be determined, the beds for two or three miles west of the Palisades, that is those along the valley of the Hackensack river, are chiefly fine-grained sandstone and shale. Some conglomeratic layers occur, but they are few and of no great thickness. Numerous exposures can be found along the road on the west side of the Hackensack from Orangeville north to New City and Short clove. Near Orangeville there are ledges, typical of the conglomeratic phase of the sandstone. The finer sandstone and shale phase is well shown near the old mill, north of Clarksville, and along a tributary stream toward Bardonia.

Ascending higher in the series, the beds become more conglomeratic. Pebbles often several inches in diameter are scattered through the sandstone beds. Lenses of conglomerate several inches to a few feet in thickness occur. Sometimes these are sharply differentiated from the sandstone beds, but more frequently they grade into each other just as the sand and gravel layers do along many streams or on the seashore. The pebbles are usually of sandstone, quartzite, quartz, slate and feldspar. The absence of gneiss, granite or schist pebbles is conspicuous and remarkable, inasmuch as the higher one ascends in the series, the nearer one approaches the borders of the crystalline area, from whence such pebbles might have been derived. Good examples of such sandstones and conglomerates are found 1) in Monsey glen, 2) on the southeast side of Union Hill, Suffern, 3) two miles east of Suffern, 4) just east of Spring Valley, 5) one and one half mile east of Pomona station, near G. W. Johnson's, 6) a mile north of the preceding locality and 7) at numerous points along the road which skirts the south side of the high trap ridge east of Mt Ivy station. Many other small exposures are found at various points along the roads or stream beds, but it is obviously impossible to mention them all.

Calcareous conglomerates

As one approaches within three of four miles of the northwestern border of the formations, limestone pebbles, cobbles and even boulders several feet in diameter appear in greater or less

numbers in the conglomerate layers. They are not everywhere present in equal numbers at equal distances from the border, nor in the same horizon. Locally they form almost the entire mass of the conglomerate beds, and here the largest fragments are always found. No sharp lines can be drawn between 1) the conglomerates made up almost entirely of limestone, 2) those containing limestone pebbles with an equal or greater number of sandstone, quartzite and quartz pebbles and 3) those which contain no limestone at all. Even were the bed rock everywhere exposed, it is doubtful whether such differentiation could be made. Every gradation between conglomerate composed essentially of limestone pebbles and conglomerate with no limestone is apparently present. The gradations occur not only in successive horizons from east to west, but apparently along the strike of the beds. The localities where the limestone phase of the conglomerate is most marked are all close to the northwestern border of the formation, but not all the beds along this border are equally calcareous. Some of them contain comparatively little limestone.

The limestone fragments have usually a reddish or bluish tinge and are often somewhat angular or but slightly rounded. Boulders several feet in diameter have been seen surrounded by a mass of smaller fragments, the whole being bound together by a red mud cement. Where purest, the rock has been quarried and burnt for lime. In appearance it resembles exactly the famous Potomac marble, found at Point of Rocks (Md.)

Similar calcareous conglomerates are known to occur at a number of places in New Jersey. They are always located near the northwestern border of the formation, as is the case in New York. So far as known, limestone does not always occur along the border, where these conglomerates are found. In no case however in New York was it possible to prove that a narrow strip of limestone might not be present between the conglomerate and the gneissic and granitic rocks of Ramapo mountain. If present, it must be in many cases an exceedingly narrow strip. The entire absence of any gneissic or granitic pebbles in these conglomerates, though they are in some cases only a few hundred yards from

the crystalline hills, is significant. It is impossible to suppose that the conglomerates were derived from the older rocks which now immediately adjoin them. The waves of the sea in which the Newark beds were deposited did not beat against the rocks which apparently now border this area. These conclusions are fully substantiated by the facts as shown in New Jersey, where the evidence is more decisive.[1]

The facts furthermore demonstrate that these border conglomerates do not mark any definite horizon. Traced away from the border along the strike, they are found to grade into sandstones and shales. This relationship again is more clearly seen in the case of the border conglomerates of New Jersey.

Local details. On the southeastern flank of Union hill, Suffern, coarse sandstone and conglomerate beds are exposed in a series of ledges, 10 to 25 feet high. The conglomerate is composed of quartzite, sandstone, limestone and quartz pebbles. One limestone boulder three feet in diameter is shown. The limestone constituent forms from 25% to 30% of the whole.

Two and one half miles northeast of Suffern is exposed, in the Crum quarry, a most remarkable conglomerate, made up of huge limestone boulders, some of which were reported to be 12 feet in diameter. The quarry is partially filled with water, so the report could not be fully verified, but boulders four and five feet in diameter were seen. The limestone is a dark bluish black rock, somewhat saccharoidal in appearance. Chert nodules occur in some boulders. The smaller fragments are sharply angular, but the larger boulders are fairly well rounded. Careful examination was made of the surface of two of the largest which were accessible, to see whether they bore traces of glacial action. None were found. A red, micaceous mud matrix cements the whole together. Owing to the heavy drift deposits, it is impossible to say how far beyond the limits of the quarry the conglomerate extends.

About three fourths of a mile northeast of the quarry, several small exposures of a somewhat similar rock were noted near Blauvelt's plow works.

[1] Annual report of the state geologist of New Jersey for 1897. p. 52-56.

A mile and a half northeast of Blauvelt's foundry is a place called Limekiln. Here many years ago the calcareous conglomerate was quarried somewhat extensively and burnt for lime. In the quarry, beds of massive conglomerate containing boulders two feet in diameter occur. Interbedded with the conglomerate are thin layers of silicious sandstone. Similar rocks outcrop at intervals for some rods from the quarry, but the highly calcareous conglomerates do not extend uninterruptedly to the exposures near Blauvelt's foundry. Calcareous conglomerate interstratified with beds of sandstone also outcrops along the road a mile and a half southwest of Ladentown.

The above are the important localities where the highly calcareous conglomerate is known to occur. A series of ledges of coarse sandstone, interbedded with thin conglomerate beds, occurs for over a mile along the top of the ridge west of the New Jersey and New York railroad between Pomona station and New Hempstead station. The conglomerate beds, because of the numerous limestone pebbles contained in them, are more easily weathered by solution than the silicious sandstones, and the latter therefore project as shelves for 1 or 2 feet. Other localities where the sandstone and more silicious conglomerate can be seen have already been noted.

Thickness. Only a part of the Newark beds are represented in the New York area. In consequence of faulting along the northwestern border, the upper beds are wanting and the bottom beds are concealed beneath the waters of the Hudson. The thickness is consequently much less than in some parts of New Jersey, but, on account of the impossibility of making correct allowance for unknown faults which may repeat the beds, no estimates were made. Estimates of the maximum thickness for the series in New Jersey varied from 11,800 feet to 14,700 feet, but even here the presence of several unknown factors may have introduced a large error into the figures.

Trap rocks

In addition to the sedimentary bed described above, another and very different type of rock is found within this area. It is usually a dark green or gray color when fresh, but a yellowish, rusty brown on weathered surfaces. When examined with a hand lens, it is often seen to be composed of small, interlocking crystals, some of which have sharply defined and regular boundaries. Its texture is quite different from that of the sandstone, which is clearly made up of rounded particles held together by some cementing matrix. Moreover, this rock does not occur in thin, regular beds as do the sandstones and shales, but is massive, generally without regular partings, though often broken into irregularly shaped fragments by innumerable cracks. It is commonly called trap rock, more specifically diabase. By its composition and structure, it is known to have once been in a molten condition. While in this condition, it was forced up from the highly heated interior of the earth into the overlying sedimentary beds, where it cooled and solidified. The trap occurs in several areas, the largest being that of the Palisades.

The Palisades. The Palisades ridge begins at Bergen Point (N. J.), and extends northward along the Hudson river to Haverstraw, where it curves westward away from the river and disappears beneath glacial deposits near the western border of the Newark formation. The same rock is found on Staten Island, but does not form a marked ridge. From Bergen Point to its disappearance a few miles west of Haverstraw its length is over 46 miles. There is much reason for believing that this rock extends many miles southwestward from Bergen Point, but absolute proof of this is not at hand.

Width. At the state line its outcrop is a mile in width, but decreases at Sparkill to only $\frac{5}{8}$ of a mile. Thence northward it increases, attaining a breadth of $1\frac{1}{4}$ miles at Bight, whereas at Nyack its width has again decreased to $\frac{5}{8}$ of a mile. West of Upper Nyack it attains its maximum width, 2 miles, from which it decreases to less than 40 rods, north of Rockland Lake.

Plate 3

The Palisades. Verdrietege Hook, north of Nyack

This extreme narrowness is due to a slight extent to the way the glacial drift is banked up against the southwestern margin. But the actual thickness of the sheet here is undoubtedly much less than farther south. At Long Clove its width is about 100 rods, and near High Tor, at Haverstraw, from $\frac{5}{8}$ to $\frac{3}{4}$ of a mile. Westward its width slowly decreases, till the rock is last seen at a small outcrop in the railroad cut south of Mt Ivy station on the New Jersey and New York railroad.

Hight. In general the trap rock forms a high massive ridge with a steep and in places precipitous eastern or northern face and a much gentler westward slope. Locally the latter is as steep as any part of the eastern face except where the former is marked by high cliffs. The hight above the river varies greatly. Just north of the state line the top of the ridge is broad and flat, and barely 200 feet above sea level. Southward in New Jersey it rises to hights of about 550 feet, whence it descends gradually and regularly to sea level at Bergen Point. The New Jersey Palisades are distinguished for the evenness of their crest line and the absence of deep gaps or notches. This is not the case in New York. At Sparkill the broad 200 foot gap is cut through almost to sea level by the gorge of Overpeck creek. Northward the crest line rises abruptly to a series of knobs whose hights range from 600 to 700 feet. On the very summit of one of these knobs is perched a huge glacial boulder of gneiss, shown in plate 1. West of Nyack the sag in the ridge is only 240 feet above the sea level. The hight at Hook mountain is 730 feet; east of Rockland lake 610 feet; at High Tor, where the maximum is reached, 832 feet; and at Little Tor 710 feet. Where it disappears in the railroad cut, the elevation is 440 feet above the sea. Between Nyack and Haverstraw the ridge is broken by four gaps, the bottoms of which have closely accordant altitudes, as shown by these figures: Rockland Lake 210 feet, Trough Hollow 190 feet, Long Clove 230 feet and Short Clove 210 feet.[1] Plate 2 shows the two latter gaps as seen from the southern side of the ridge. In addition to these there is be-

[1]These hights are taken from the U. S. topographical atlas, and are subject to a plus or minus correction not exceeding 10 feet, provided the map is accurately drawn.

tween Piermont and the state line the broad depression whose elevation is about 200 feet. The accord in the hight of these gaps is probably not a mere coincidence but the result of certain geographic conditions which no longer exist. The gaps are undoubtedly the result of erosion and probably mark a period when the elevation of the land was about 200 feet less than at present. At this time the streams cut down their channels across the trap ridge about to base level. Subsequent elevation of the region seems to have given opportunity for readjustments in the drainage lines, by which most of the streams escaped from the hard trap rock, and gained courses on the softer sandstones. A stream, however, maintained its course across the sag near Sparkill, and has since eroded a narrow gorge through the ridge almost to the present sea level.

Relation to the sandstones. The trap forms an intrusive sheet or sill lying between the layers of sandstone and dipping with them at a gentle angle westward. This relationship accounts for the steep and precipitous eastern face and the gentler westward slope. The trap does not, however, everywhere occupy the same horizon between the sandstones. There are many places, particularly in New Jersey, but also in New York, where it visibly crosses the sandstone beds from one horizon to another. These unconformable contacts have been found along both the under and the upper margins, and afford clear and indisputable evidence that the trap was forced into its present position between the sedimentary rocks in a molten condition, and that it did not come to the suface and overflow as do lava sheets from volcanos.

For most of the way from Bergen Point (N. J.) to Rockland lake the trap is intercalated between the beds of sandstone at slightly discordant horizons and dips westward with them. There is, however, evidence at a number of localities along the western side to suggest that the steeply inclined vertical fissure up which the molten rock ascended is located close along this margin.[1]

[1]This relationship was noted many years ago by N. H. Darton, U. S. geol. sur. Bul. 67, p. 37. So also were a number of the local details to which I shall make reference below. In the preparation, however, of this report I have made use only of my own observations in the field, unless otherwise expressly stated.

This assumed relationship is indicated by the diagrammatic cross-section shown in figure 1.

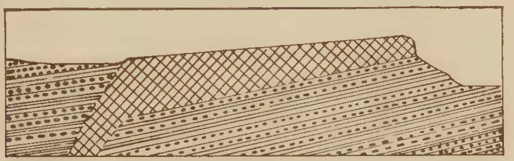

Fig. 1 Diagrammatic cross-section of the Palisades trap ridge, showing its probable relations to the sandstones. The thickness and position of the feeding dike are largely hypothetical.

From Rockland lake northward the trap ridge curves gradually to the left so that it crosses the strike of the sandstones at a continually greater angle. West of High Tor, near Haverstraw, its trend is at right angles to the sandstones which outcrop close to the southern margin. This change of trend is due primarily to a change in the trend of the feeding dike, which here bends westward. At the same time, however, the base of the sheet ascends from lower to higher horizons in the sandstones. The ascent is sometimes made by abrupt steps and in other cases by a gradual oblique trend. These changes are best shown between Rockland lake and Haverstraw, and instances of both will be cited below. West of Little Tor, near the end of the hook, the trap apparently loses much of its sheet-like character, while at the same time the dike characteristics are more marked. It does not, however, become a simple dike, since at various places there is slight evidence to show that the lava spread between the beds laterally from the fissure up which it ascended. Details of the structural relationship are noted below.

Local details of the structural relations. The basal contact is the one most frequently exposed. At Sneden's landing it has an elevation of about 120 feet above the river, and ledges of arkose sandstone and varicolored shales are exposed beneath the trap, but the actual contact is not revealed. Northward the base of the trap gradually descends in elevation till just south of Overpeck creek, Piermont, it passes beneath the level of the river.

This change of elevation is apparently due, not to any change of geologic horizon, but to the westerly trend of the escarpment as compared with the strike of the sandstone. On the north side of the creek, near the lower railroad track, Piermont, the contact is 60 feet above sea level, the change in elevation being due to a fault which crosses the ridge diagonally from northeast to southwest, along the line of the creek, and which has raised the northern block relatively to the southern. Good examples of the way the trap is broken by many joints into small wedge-shaped fragments are found in a small exposure here, which also shows another phase of trap disintegration, i. e. that of concentric weathering—figure 2.

From Piermont north to Verdrietege Hook, or Hook mountain, a distance of 5 miles, the basal contact is not exposed, but it is possible to determine its position quite accurately. From an elevation of 60 feet at Piermont it ascends to 240 feet, a mile north of Piermont, to about 400 feet south of Nyack, and thence descends to 220 feet in the gap west of Nyack. This ascent is accompanied by a departure of the cliff face from the Hudson river, so that at Nyack it is from ½ to 1 mile distant. Within this distance the sandstones strike slightly east of north, and the increased elevation of the base of the trap in spite of a trend which decreases the altitude of the outcrop can be explained only by supposing it to have ascended to higher geologic horizons. The descent from 400 to 220 feet west of Nyack is due to erosion at the gap and the westward dip of the contact plane.

Where the trap crosses the road from Rockland lake to Nyack (*a*, fig. 6) its base is about 320 feet above the sea level, which indicates a slightly lower geologic horizon than farther south. Just north of this point the trap escarpment, which for several miles has not been precipitous, though always a steep slope, turns abruptly eastward almost at right angles with its former course and approaches the river to form the bold and naked cliffs at Verdrietege Hook, so well shown in plate 3. This view well illustrates the mural face of the Palisades where they are boldest. The top of the ridge is tree-clad. The cliff is often 200 or more

Plate 4

High Tor south of Haverstraw. The highest knob of the Palisades ridge

feet in hight, and at its foot are the long lines of talus, composed of huge angular blocks broken by frost action from the precipice above, and only partially concealed by a few trees. The naked talus slope is also well shown south of Haverstraw near Short Clove. The highest knob shown in the view has an elevation of

Fig. 2 Weathered trap at Piermont.

730 feet above the river and 550 feet above the flat at its foot. The base of the trap usually lies a few feet below the foot of the cliff and beneath the upper limit of the talus.

At the Manhattan trap rock quarry shown in plate 3, just beneath the knob at the right, the contact has been exposed. At the time of my visit, the trap at the south end of the quarry could be seen cutting across the sandstone obliquely downward to the north, a distance of about 35 feet in 60. Thence it followed conformably the bedding planes and gradually regained its former elevation above sea level, though still at a lower geologic horizon.

Its general elevation at the quarry is about 260 feet A. T. If the base of the trap kept to the same horizon which it has where it turns so abruptly eastward at Verdrietege Hook, the rise of the underlying sandstones up the dip would carry it from 620 to 660[1] feet higher above sea level than it actually is at the quarry. The evidence seems conclusive therefore that the abrupt turn at Hook mountain north of Nyack, is due to the descent of the base of the sheet to a geologic horizon 600 or 700 feet lower than that occupied where it crosses the Rockland lake–Nyack road.

From the quarry at Hook mountain for several miles northward the position of basal contact can generally be determined best from a boat. A mile north of the Manhattan trap rock quarry, near the powder house landing, the contact is beneath the water level for 150 yards, a large part of the descent from the quarry level (260 feet) being caused by its breaking across the sandstone beds. Just south of where it reaches the river, a ledge of sandstone 30 feet thick is exposed along the shore, and the trap must be at least 50 feet above the water.

Northward the base of the trap rises again across the beds of sandstone as represented in figure 3 to a hight of about 50 feet above the river. From this point it lies conformably on somewhat indurated shales, the outcrop of which slowly descends, so that within a half-mile the base of the trap sheet is again below the water level for a distance of 75 yards. This exposure is directly beneath the southern end of the Rockland Lake trap rock company's quarry (*a*, fig. 4). Immediately to the north the base of the trap must ascend across the beds of metamorphosed shale, since the latter are next exposed along the river with the base of the trap several yards above them. After this ascent the trap again becomes conformable with the shales, the trend of which once more brings the contact beneath the water level 100 yards

[1]It must be understood that these figures and many others given in this report are subject to some variation, owing chiefly to possible variations in the angle of dip. In this calculation a variation of 1° makes a difference of 40 to 50 feet in the result, and it is not always easy to determine the angle of dip within 1° with the small clinometer the geologist uses. This is particularly the case if the rock exposure is obscure.

south of the Rockland lake landing (*b*, fig. 4). 100 yards north of the landing (*c*) a welded contact of fine grained trap resting on highly metamorphosed shale is exposed near the water level in the bed of a small brook. Just north of this, brown sandstone outcrops at a higher level, showing that here again the trap ascends at least 25 and probably 75 feet across the beds. Between these exposures north and south of the landing, the base of the trap seems to be near the water level. The evidence appears to show that there is no change of horizon at the gap just back of the landing. This point is of importance in determining whether or not the gap is located on a fault line. Though not conclusive, the evidence is strongly against the fault hypothesis.

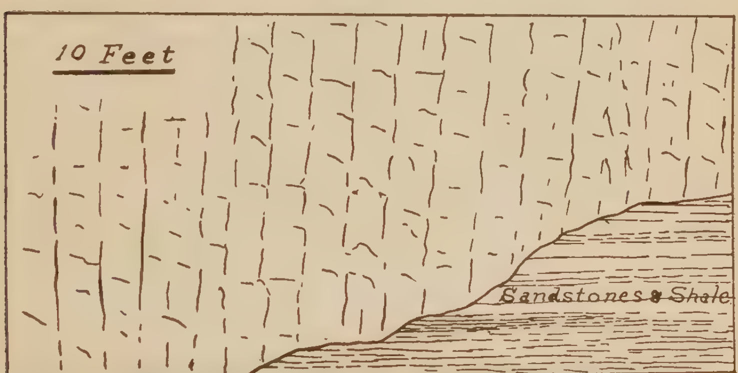

Fig. 3 Basal contact near the powder house one mile south of Rockland Lake landing.

From Rockland lake landing northward the trend of the shore constantly brings higher beds down to the level of the river. The base of the trap must, therefore, soon be carried below sea level, unless it changes to higher geologic horizons. At the locality last mentioned the contact rises by crossing the beds to an elevation of at least 75 feet above the river. Thence it is in part conformable to the shales and in consequence slowly descends to about 25 feet above the river at the Cosgriff trap rock quarry (*d*, fig. 4) at Trough Hollow. Whether in this interval of half a mile it changes its horizon is unknown, as the actual contact is not shown.

At the stone-crusher near the quarry the basal contact ascends abruptly for at least 20 feet, but it is not clear whether the ascent is caused by a fault or by breaking across the beds. The gap at Trough Hollow, particularly when viewed from the river, has some appearance of a fault gap, and the alignment of the escarpment is slightly broken, as if offset by an oblique fault of small throw. The relations near the stone-crusher lend strength to the fault hypothesis, though they do not establish it beyond a doubt.

In the quarry the trap rests on brown, feldspathic sandstone. North of the quarry these beds can be traced continuously till they disappear beneath the river, while the base of the trap ascends to an elevation of between 100 and 200 feet. The small fault which may cut the trap at Trough Hollow can not account for this. On the contrary, the topography suggests that the base of the trap ascends obliquely at an angle of about 15°.

Between Trough Hollow and Waldberg landing at Long Clove, 2½ miles, the base is not exposed, but is high up the face of the bluff, at elevations varying from 150 to 250 feet above the river. It is certainly not conformable for all this distance, since the dip and trend of the shales are such as to carry outcrops downward and out of sight at a rate varying locally from 300 to 900 feet a mile. The fact that within the distance mentioned above (2½ miles) the contact remains high above the river proves that the base of the trap must ascend geologically many hundred (1000 to 1500) feet (*d* to *e*, fig. 4).[1]

A few hundred yards below the quarry at Long Clove (Waldberg landing) a dike of trap varying from 3 inches to a foot in thickness cuts the arkose sandstones which lie at least 50 feet below the main trap sheet. The dike in general follows a meandering, wavy course nearly parallel to the bedding of the sandstone, and can be traced for 50 yards or so. At one point it shows the relations represented in figure 5.

At Long Clove the base of the trap changes its elevation somewhat. Whether it is due to faulting or to a change of horizon is not clear. Seen from the river, the gap of Long Clove did not im-

[1]The vertical scale is exaggerated nearly three times the horizontal, consequently the dip of the sedimentary beds is too great.

press me as being a fault gap. The rise of the contact is apparently somewhat gradual, indicating an unconformable contact rather than a fault.

At Short Clove there is another small change of elevation, of not more than 30 feet, due possibly to a small fault or to another unconformable contact. The base is here about 180 feet above the river. From this point west to the end of the ridge no definite statement can be made as to the structural relations which prevail between the trap and sandstone along the northern border. Nowhere is the actual contact revealed. At only two localities has the sandstone been found anywhere near the trap. At one of these, an old quarry under Little Tor, the strike of the sandstone is nearly at right angles with the trend of the trap ridge, and the beds dip 10° westward. Two layers of trap having a maximum thickness of 4 feet have been intruded into the sandstones in this quarry. They can be traced for about 25 yards generally conformably to the sandstones, and finally disappear by petering out. The sandstones near the dikes are unaltered. Their junction with the main trap mass is not shown. At the other locality near the terminus of the ridge, the conglomeratic sandstones dip toward the trap as if they passed beneath it. It is impossible to say whether, from Short Clove westward, the trap and sandstones abut against each other along a steeply inclined contact plane which trends parallel to the direction of the ridge, i. e. a dike contact,

Fig. 4 Section showing the unconformity of the trap and sandstone along the Hudson river near Rockland landing.

or whether the trap rests on successive beds of sandstone in a series of steps which ascend westward.

The upper contact. Much less is known of the upper contact of the trap and shale. For most of the distance the trap disappears beneath the glacial drift, and its actual contact with the shale is not visible. From the state line to Sparkill its position can not be accurately located, owing to the thick drift deposits. At Sparkhill there is an abrupt offset of $\frac{1}{4}$ mile corresponding to the offset of the basal contact, caused by the fault along the line of Overpeck creek.

From Sparkill northward to West Nyack the upper contact apparently crosses the strike of the shales somewhat obliquely. East of Orangeburg and 2 miles north of Sparkill the westward slope of the trap ridge is marked by cliffs, a fact which suggests that here the feeding dike rises above the surface. The same feature was noted 2 miles farther north near the Clarkstown-Orangeburg township line.

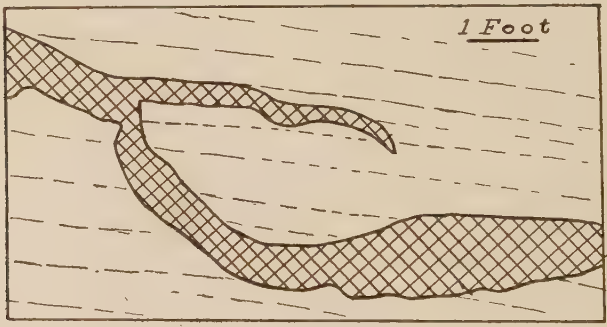

Fig. 5 Dike in the sandstone beneath the Palisades, south of Long Clove.

The actual contact of trap and sandstone is shown a quarter of a mile south of the Nyack-Clarksville road, along the road to Sparkill (*b*, fig. 6). It is not conformable to the sedimentary series, and fragments of highly indurated shale and sandstone, 6 to 15 inches in diameter, are included in the upper part of the trap. The latter is fine grained but not vesicular nor amygdaloidal.

North of West Nyack the margin of the trap outcrop is more irregular than at any other point along its entire length in both New Jersey and New York. A spur of the ridge half a mile wide juts out to the west for about a mile. At the northern and southern ends of this spur there are smaller masses of trap, ¼ mile in length, which may be connected with the greater mass, though separated from it by erosion depressions in the bottom of which all rock outcrops are concealed by glacial drift and alluvium (*c*, *c*, fig. 6).

East of Valley Cottage (*d*, fig. 6) numerous bosses of fine grained trap are exposed, in several of which masses of indurated, fine grained sandstone are imbedded. Some of these inclusions have a width of several feet. They are masses of the sandstone which

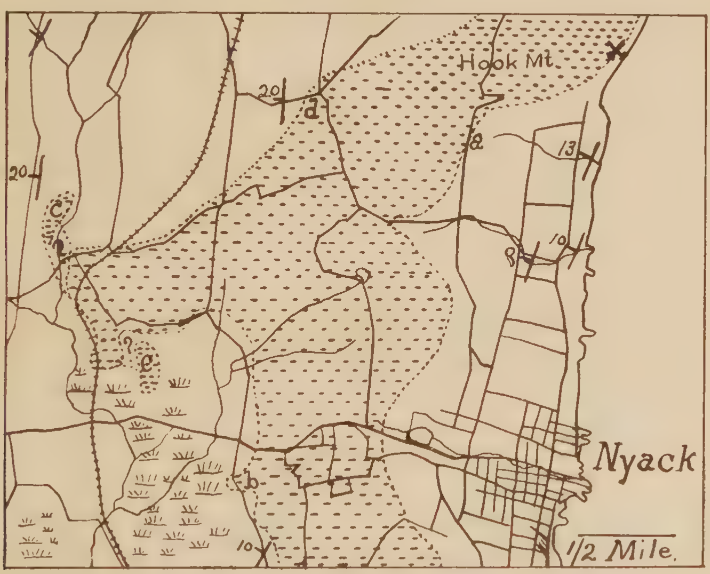

Fig. 6 Map of the region near Nyack.

were broken off and incorporated into the upper part of the trap during its intrusion in a molten condition. Their occurrence is conclusive proof of the intrusive origin of the sheet.

From Valley Cottage the boundary extends a little north of east, nearly parallel to the eastward bend of the basal margin at

Verdrietege Hook. It follows along the eastern side of Rockland lake and thence northwestward, but for several miles the sandstone is nowhere exposed near it. But just south of the entrance to the tunnel of the West Shore railroad, near Long Clove, the contact is finely shown. The relations here have been pictured and described by Darton,[1] and are represented in figure 7. The trap ascends by steps across the sandstone, which has been altered for a distance of 20 feet from the contact. This exposure better than any other shows the dike-like character of the upper contact. The sandstones dip gently westward (away from the observer in the diagram), and the contact line crosses their strike at a steep angle.

Outcrops of highly indurated shale (hornfels) and trap occur along the road leading south from Long Clove in such relationship to each other as to show that the line of contact is here an irregular one. The shales dip northeast toward the trap at a steep angle, the departure from the normal westward dip being probably due to deformations caused by the intrusion of the trap.

West of Short Clove the border is very irregular in places. In general it lies above and to the north of the road skirting the ridge, but it often changes abruptly in elevation and direction, showing that the trap must zigzag across the sandstone beds in a more complicated manner than farther south. Its dike-like character is clearly evident. The relations shown by figure 8 were noted near the corner, where the road turns south to New City. The contact is exposed for a distance of 4½ feet. The sandstone dips away from the observer and obliquely to the left (west) and shows no signs of metamorphism near the trap, a somewhat unusual occurrence. The contact line here trends northward, nearly at right angles to its general course.

A mile farther west there is some evidence that a small tongue of trap extends from the main mass into the sandstone, but the exact relations are obscured. Outcrops of sandstone are common for several miles west of Short Clove, and the location of the contact line can generally be accurately determined.

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[1]Darton, N. H., U. S. geo. sur. Bul. 67, p. 51 and fig. 26.

Effect on the neighboring shales and sandstones. Both the under and overlying beds have been more or less metamorphosed by contact with the trap. The most marked macroscopic changes are 1) a greater induration, 2) a change in color, red shales in general becoming, near the trap, purple and then a blue black, streaked with gray or green, and 3) the development of secondary minerals, commonly epidote and tourmalin. The rock sometimes has a banded or mottled appearance, due to the formation of lime-silicate hornfels.

The alteration has been most pronounced in the case of the shales. Beds of sandstone are less altered, particularly in color and in minerals, though not infrequently somewhat indurated. The red shale has sometimes been altered to a very hard, black, flinty rock, sometimes mottled or banded and known as hornfels.

In New Jersey the contact metamorphism has been more complete, and has affected the beds for much greater distances from the trap, than in New York state. The shales are often completely altered for over 100 feet from the contact, and traces of metamorphism are discernible for still greater distances. In no case was such widespread and extensive alterations noted along the Palisades in New York state. I know of no place where intense alteration has affected the beds for more than 25 or 30 feet, and very often unaltered sandstones or shales are found much closer than that to the trap. One or two localities have been noted where the rock adjoining the trap is entirely unchanged, a condition never seen farther south.

The lesser metamorphism at the northern part of the Palisades is, I believe, due chiefly to two causes. The first is the texture and composition of the inclosing beds, and the second is the position of the trap, i. e. the geologic horizon it occupies. Other conditions being the same, the silicious sandstones have been less altered than the argillaceous and calcareous shales. Since in New York state the adjoining layers are more frequently sandstones than in New Jersey, the metamorphism is less marked. But more important, I take it, than the texture or composition of the beds is the horizon the trap occupies. In New York state

it is higher in the series than in New Jersey, and therefore it cooled nearer the surface and probably more rapidly. Its own temperature at the time of intrusion may also have been less. West of Haverstraw the trap occupies a much higher horizon than farther south. The cases of more extensive alteration occur along that part of the sheet which lies at the lowest horizons, whereas the cases of no alteration occur where the trap is highest in the series. The facts seem to indicate that the trap reached the higher horizons in the sedimentary series with a somewhat lower temperature and, being nearer to the surface, cooled faster than at greater depths. Its effects therefore on the surrounding beds were less marked. Other causes may have contributed to this result, but the two mentioned are believed to be the chief ones.

Local examples of metamorphism. At Piermont indurated arkose sandstone is exposed near the trap, below the railroad station, and a mile north of the station a small exposure of hard straw-colored sandstone and black hornfels was found in the bed of a small stream, about 10 feet below the trap.

At the Manhattan trap rock company's quarry, Verdrietege Hook, the shale beneath the trap is dark blue or gray colored and somewhat indurated. Where the trap cuts across sandstone, there is but little change in the latter. The contact metamorphism even where most marked, can hardly be detected in beds 30 or 40 feet away. The exposures here afford good opportunity for comparing the relative alteration of shale and sandstone under similar conditions of heat, pressure, etc.

Good examples of highly altered shale (hornfels) occur 100 yards above Rockland lake landing, and less intensely altered shales are exposed at the water's edge just below the southern end of the quarry at the landing. At the Cosgriff quarry at Trough Hollow, shales within 20 feet of the trap are slightly changed in color, but sandstones are not visibly altered.

At the southern entrance to the West Shore railroad tunnel at Long Clove, the shales are indurated for not more than 20 feet from the trap, and even at the contact, the metamorphism is not intense.

Near West Nyack and again near Valley Cottage masses of highly altered sandstone and shale are found inclosed in the upper part of the trap, but there are no means of determining for how great a distance the overlying shales are affected. Again a

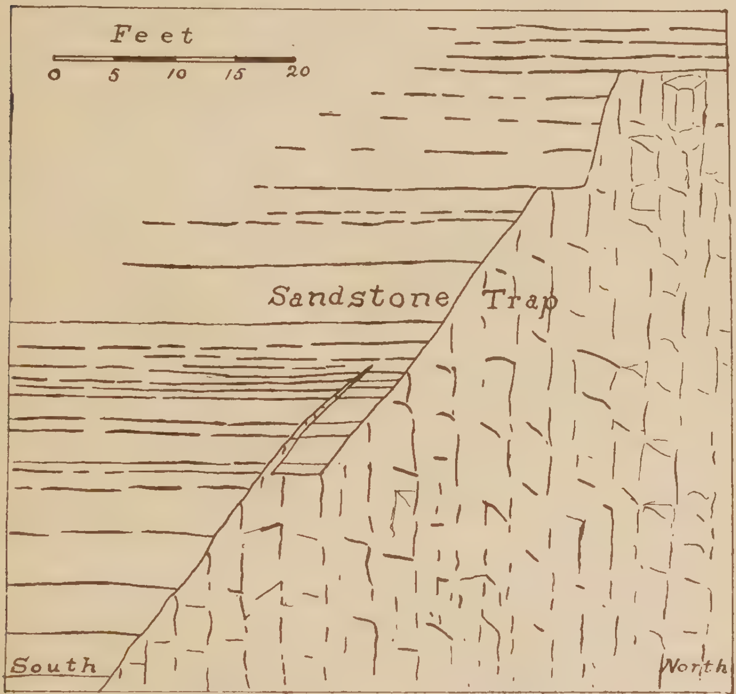

Fig. 7 Contact of the trap and sandstone south of the entrance to the tunnel of the West Shore railroad near Haverstraw. The sandstones dip away from the observer westward.

ledge of highly altered slate (hornfels) outcrops a few feet from the trap along the road leading south from Long Clove.

West of Short Clove no cases of metamorphism were noted, though the sedimentary beds were often exposed close to the trap, and in one locality, figure 8, the actual contact was seen.

Other effects than metamorphism. In general the trap has no effect on the sedimentary beds other than specified above. The latter were not disturbed beyond the movement necessary to provide room for the intruded mass. The overlying beds were gently raised, apparently without any great distortion. Where the trap

crossed the beds from one horizon to another, it did so without crushing or bending the strata to any extent. There must have been some lateral crowding, as the beds were pushed aside to make room for the ascending sheet of lava, but no evidence of any great dislocation has been found. Locally there are slight variations in the strike and dip of the beds near the trap, but these are not abundant. Indeed, it is a source of surprise that the intrusion of so great a mass of trap was not accompanied by greater dislocations in the inclosing strata. There is no evidence that the beds were faulted by the intrusion of the trap, nor that the prevalent westward dip is due in any respect to this cause. And of course the idea, prevalent among so many, that the beds were lifted above sea level, and that the present topography and elevation of the Palisade ridge itself is due to volcanic forces, is entirely without foundation.

Thickness. Estimates of the thickness of the trap sheet vary greatly, partly because of great variations in its actual thickness and partly because of the difficulty of making accurate estimates in the case of a sheet, cut by faults, whose structural relations are more or less obscure, and which has lost something by erosion.

At Weehawken (N. J.) the thickness is estimated to be between 700 and 875 feet. At Fort Lee (N. J.) a well penetrated 875 feet of trap before reaching the underlying shale, and probably 75 feet more must be added for the amount lost by erosion. At Piermont the thickness is estimated to be about 850 feet. At Upper Nyack, where the width of outcrop is over 2 miles, the structural relations are too indefinite to permit an estimate of much value, but the thickness seems to be at least twice that at Piermont. East of Rockland lake the base of the trap is slightly below sea level, and the crest of the ridge has an elevation of 610 feet. To this must be added about 300 feet more, owing to the fact that the trap here dips westward at an angle of 13°. Even then our 900 feet gives only a minimum thickness, since no allowance has been made for loss by erosion on the crest. North of Rockland lake, where the width of outcrop is about ⅛ of a mile, the minimum thickness may not be more than 250 feet, though here the glacial

drift, which is banked up against the western side of the ridge and obscures its true margin, adds an element of uncertainty to these figures. At High Tor, plate 4, the crest of the ridge is 832 feet above the sea level, or about 530 feet (estimated) above the base of the trap. But here again an unknown amount has been lost by erosion, and therefore this can be taken to represent only a part of the total thickness of the trap at this point. Moreover the structural relations here are so indefinite that it is impossible to determine with any accuracy what the maximum thickness may be.

Ladentown trap. South of the little hamlet of Ladentown and almost within the shadow of Ramapo mountain, on the western border of the Newark beds, there is another trap area. Its greatest length is about 2 miles, measured from northeast to southwest, and its maximum width is nearly a mile (fig. 9). Its northwestern margin rises steeply above the valley of the Mohawk creek, and is sharply marked topographically. Elsewhere the boundary is not sharply differentiated by a change of topography. Along the road leading southwest from Ladentown, the trap forms a continuous ridge deeply trenched in a number of places by streams. On the eastern side, also, there is a less well marked ridge. Between these elevations there are a number of knobs and hillocks of trap, separated by wide and deep depressions which are encumbered with drift.

The topography suggests that the entire area is not trap, but that there are some masses of sandstone inclosed in the trap. At one or two points slight confirmatory evidence was noted, but the thickness of the drift is so great as to prevent positive determination of this point. Within the area, therefore, marked as trap there may be masses of shale, but the data in hand do not warrant an attempt at separate mapping.

Vescicular trap was noted at several points, particularly at point A, figure 9, and at the northern end near Ladentown (B) a ledge showed some indication of the ropy-flow structure so characteristic of extrusive sheets.

Relations to surrounding beds. The sedimentary beds are nowhere exposed in contact with the trap, but at a number of points outcrops occur not far away. A mile and a half southwest of Ladentown (C) ledges of calcareous conglomerate dip toward the trap at angles varying from 5° to 12°, and apparently pass under it. On the eastern side of the trap somewhat similar beds (D) dip westward to an angle of about 5°. This suggests that in a cross-section drawn from C to D, figure 9, the structure would

Fig. 8 Contact of the trap and overlying sandstone, south of Little Tor (from a photograph).

be as represented in figure 10, A. At point E the conglomerate dips 12° southeastward, and then at the limekilns (F) the dip is 5° northwestward. The relations along a line E to F and crossing the trap may be as represented in figure 10, *b*. In both cases the relations shown by these sections can not be regarded as more than suggestive.

Relation to Palisades trap. Previous observers have made this trap a part of the Palisade sill. Between the two there is a deep gap nearly 2 miles wide within which but one outcrop of trap is known (G, fig. 9). At another point (H) within the gap coarse sandstone is known to occur. Elsewhere the rock, whatever it is, is deeply buried beneath glacial and swamp deposits. The data in hand indicate that, if the trap is continuous across the gap, the connecting belt must be much narrower than the Ladentown area,

and that it has been worn down to a much lower level in the gap than on either side. Branches of Minisceongo creek drain northward through this gap. Data are at hand to show that a wide and deep, drift-encumbered valley extends south from the gap for several miles in the sandstone, and also northward toward the village of Thiells. No exposures of rock were found along it, even where the streams have cut deep gorges in the drift. Thus it is entirely within the bounds of possibility that the trap of the Palisades ridge which is last seen in the railroad cut 400 yards south of Mt Joy station underlies the swamp to the west and is connected with the trap area near Ladentown.

The Ladentown trap is very fine grained, more so than that of the Palisades ridge. It is moreover frequently vescicular and shows some evidence of a ropy structure, characteristics which are nowhere known to occur along the Palisades sheet, but which

Fig. 9 Sketch map showing relations of trap and sedimentary beds near Ladentown.

are of frequent occurrence along those sheets of New Jersey which have been proved to be surface flows. The evidence is not conclusive, but the data suggest that the trap of the Ladentown area reached the surface and overflowed.[1] This conclusion is not in-

[1] N. H. Darton was the first to my knowledge to make this suggestion.

compatible with the assumption that it is connected with the Palisades sheet, as the latter at its apparent termination near Mt Joy has risen far above the base of the formation, and still farther west may have overflowed the floor of the estuary on which the sandstones were deposited.

Union hill trap. Near Suffern a mass of trap rises above the surrounding glacial deposits forming Union hill. Its greatest length from northeast to southwest is nearly half a mile; its width is about one half that. The rock is not vesicular, not scoriaceous, but of medium texture and suggests an intrusive mass. Its relations to the surrounding sandstones and conglomerates are unknown. The latter are exposed in a ledge below the trap along the southeastern face of the hill. The conglomerate beds dip toward and apparently pass under the trap, but they may abut against it. The latter rises from 120 to 140 feet above the line of contact, which is everywhere concealed beneath drift or talus, and it must therefore have a minimum thickness of this amount. About ⅛ of a mile north of this ledge a low boss of trap 50 feet in diameter rises above the terrace of stratified drift along the Mohawk valley. It is not known whether it has any connection with the Union hill mass.

Dikes

Dikes are not common within this part of the Newark formation. If the glacial drift were removed, more might be found. Several small ones occur midway between New City and West Nyack. One can be seen in the road directly in front of the house of H. M. Vanderbilt. Two others cross the road a few hundred yards to the east and are marked by low elevations. The most conspicuous dike is apparently from 100 to 130 feet wide and forms a broad swell, about 15 feet high, which can be traced southward from the road for 300 to 400 yards before it dies away beneath the drift. Still farther east, beyond the first bend in the road are two more dikes, making five in all. Owing to the drift, only two can be traced beyond the road, and these are lost as soon as they cease to be conspicuous topographically.

In addition to these, others can be seen at two points in the sandstones beneath the Palisades sill. At neither locality can their connection with the greater mass be traced, but it can hardly be doubted that they are downward protrusions from it. These dikes have already been described in connection with the basal contact phenomena of the Palisades.

STRUCTURE

Dip and strike

In general the sedimentary rocks form a monocline which dips gently northwestward. Within comparatively narrow limits there is considerable variation in the strike and also in the dip. But the limits are comparatively well fixed. With few exceptions the strike varies from north to n 45° e. It rarely exceeds these limits, though in a few cases the easting is as much as 60°, and sometimes the beds have an abnormal westerly strike. The dip is usually between 5° and 15°, and is apparently slightly less in the western than in the eastern half of the area. In consequence of this uniform westerly dip, the lower beds of the formation outcrop nearer the Hudson river, and as one travels westward higher beds are found.[1]

Compared with some parts of the Newark area in New Jersey the structure is simple. Over most of the area there are apparently no folds, not even very gentle ones. The monoclinal structure is practically supreme.

A few qualifications to the above statements must be made. West and northwest of Haverstraw, the sandstones dip to the southwest instead of to the northwest or west. Near Stonypoint the boundary of the Newark formation extends northwest to a point a mile from the Hudson river, where it makes a somewhat abrupt turn to the southwest, a course which is held uninterruptedly for nearly 60 miles. For the first mile back from the river the border conglomerates trend parallel to the border and

[1] This is true of course only so far as faulting has not caused a repetition of the strata.

dip southward away from the older rocks. Between Stonypoint and Haverstraw, therefore, there is the most marked departure from the northwesterly dipping, monoclinal structure.

It has already been pointed out that a shallow syncline exists near the Ladentown trap area. The beds nearest the border of the formation dip eastward away from the older rocks, whereas ¾ of a mile to the east westward dipping conglomerates are found. The extent of this syncline is unknown. It certainly does not involve the beds all along the border. Northeast of Ladentown there are

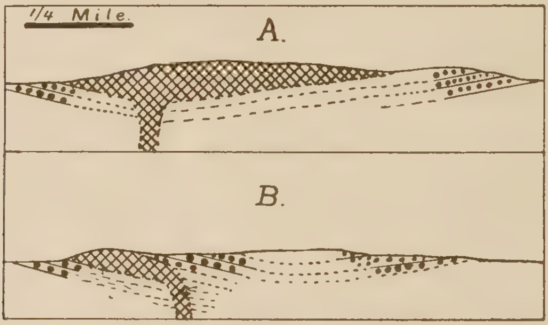

Fig. 10 Sections showing the supposed relations of the Ladentown trap to the adjoining conglomerate.

no exposures of sandstone or conglomerate for more than 5 miles, but west of North Haverstraw the rocks all dip to the southwest and west. Southwestward at Blauvelt's foundry and Crum's quarry the conglomerate beds appear to dip northwestward toward the older rocks, and at Suffern there is no doubt as to the northwestward dip and the absence of the synclinal structure.

Faults

The question of faults in the sedimentary beds is a perplexing one. Owing to the absence of any well defined horizon in Rockland county which can be readily recognized, and to the glacial drift which conceals so much of the rock surface, it is practically impossible to locate any faults in these beds save where the actual fault plane is exposed in a cliff or artificial section. In New Jersey faults of great magnitude are known to traverse the for-

mation and cause the repetition of several thousand feet of strata. Many smaller dislocations have been observed in quarries and other sections. In New York state, however, evidence of faulting is scanty. The data bearing on this question are as follows:

At Sparkill, Overpeck creek crosses the trap sheet through a gap eroded nearly to sea level, and probably located along a fault. The evidence favoring this conclusion is found first in the abrupt offset to the west of that part of the ridge lying north of the gap, and second in the greater elevation of the base of the trap north of the gap. The offset measures over 300 yards, which, if the motion were entirely vertical, would mean a throw of over 200 feet. The base of the trap has not apparently been raised that amount, and therefore the motion seems to have been a combination of an uplift and a side thrust.

At Upper Nyack a fault with throw of not less than 10 feet can be seen in a ledge of red shale a little above the river. The fault plane hades 15° west and trends about north. There are no means of telling how much more than 10 feet the throw may be.

At Trough Hollow the trap ridge appears to be slightly offset, as if a fault crossed it diagonally, and the base of the trap rises somewhat abruptly near the stone-crusher at Cosgriff's quarry. Both of these phenomena may be due solely to a change in horizon of the trap. Faulting, if present, is slight.

Some observers have seen evidence of faulting in the gaps at Long Clove and Short Clove, but, after careful examination of the ground, I was not convinced that they mark fault lines. Manifestly the gaps themselves do not necessarily indicate faulting. As already suggested, these gaps with several others of accordant hight are probably parts of a drainage system formed when the land stood somewhat lower with respect to sea level than at present. Their location may have been determined by faults, but I could find no positive evidence that such was the case. All the facts observed can be accounted for without calling in the aid of faulting. Were these gaps along fault lines, the ridge would commonly be offset, though it is conceivable that by a peculiar combination of circumstances faulting might have occurred without causing offset in the ridge.

The calcareous conglomerate shown in the railroad cut just south of Stonypoint is cut by a fault which trends 80° e, and hades 35° n. The downthrow is probably on the north and exceeds 6 feet. How much more it may be is unknown.

Northwest border. Faults have been shown to mark a part of the northwestern boundary of the Newark beds in New Jersey.[1] Much of the evidence is indirect, but it is is nevertheless convincing. A great fault has determined the boundary from a point near Peapack (N. J.) to a point about a mile west of Stonypoint on the Hudson, a distance of nearly 53 miles. The evidence of the fault is most clearly shown in New Jersey. The boundary line for this interval of 53 miles is remarkably straight. In this respect it is in marked contrast with those other parts of the boundary both in New Jersey and New York, where the structural relations are such as to demonstrate that no fault exists. The strongest proof of faulting is found in the way the Newark beds terminate against the older rocks. They dip at various angles to the border, more frequently directly toward it than otherwise. In New Jersey the western side of the great Watching mountain syncline has been cut off, so that the shales which outcrop along the border belong to very different stratigraphic horizons. At Bernardsville (N. J.) an outcrop of trap close to the gneiss shows unmistakable evidence of fracturing and shearing. The rock is literally crushed to pieces, so that it is practically a friction breccia.

In New York the fault has a more easterly trend than the sandstones and conglomerates have. Consequently, as one goes northward, lower strata are constantly found against the older rocks. From Suffern the fault follows the course of Mohawk creek, along the foot of the steep escarpment of Ramapo mountain as far as Ladentown. The gravel terraces of the creek conceal all rock outcrops for several hundred yards from the fault line, so that the actual contact is nowhere seen. At Suffern the conglomerates dip obliquely toward the crystallines. At Crum's quarry and Blauvelt's foundry, several miles northeast of Suffern, the dip is appar-

[1]Annual report of the state geologist of New Jersey for 1897. p. 110-16.

ently toward the older rocks, but these beds do not belong to the same horizon as the Suffern exposures. Southwest of Ladentown (fig. 9, *c*,) the conglomerates dip away from the older rocks.

For several miles northeast of Ladentown, the exact location of the contact and fault is rendered uncertain by high hills of glacial drift which not only conceal all rock exposures, but also obscure the rock topography. It apparently swings more to the east, passing near Camp hill and just east of the village of Thiells. Its position can be exactly located in the bed of Cedar Pond brook near the Stonypoint waterworks, where nearly horizontal calcareous conglomerates belonging to the Newark series are exposed within 10 or 15 feet of the paleozoic limestone. The contact is apparently a vertical one, the conglomerates abutting against the older rocks, though the actual contact is not shown. A few feet down stream the conglomerates have a distinctly marked westward dip, i. e. toward the older rocks. It is difficult to believe that the Newark beds rest undisturbed on the limestone. The more natural conclusion from the relations there exposed is that they have been faulted against it. A black, crumpled shale outcrops a few feet upstream from the limestone exposure, which is very narrow, and for a mile or more southward a belt of shale at least a quarter of a mile in width lies between the crystallines on the west and the Newark conglomerates on the east.

The conglomerates here adjoining the older rocks belong to a horizon undoubtedly many hundred feet below those exposed south of Ladentown, and still farther below those near Suffern. In fact I believe they are nearer to the base of the entire formation than to the top. The fact that beds belonging to such widely different horizons adjoin the older rocks is the strongest proof that faulting has occurred along this border.

Another indication of faulting is found in the composition of the sedimentary beds along the border as compared with the older adjoining rocks. I have already pointed out the absence of granite or gneiss pebbles in the conglomerate, the two constituents most to be expected, if the conglomerates had been formed in their present position relative to the older rocks. The presence

of large numbers of quartzite and sandstone pebbles is likewise difficult of explanation, unless it be supposed that faulting has eliminated the quartzite and sandstone layers, as well as the limestone strata which supplied the large boulders sometimes found, and brought the Newark beds into their present position.

West of Stonypoint the boundary line makes an abrupt bend to the southeast till it reaches the Hudson river. The older rock is limestone. The adjoining Newark conglomerates are composed chiefly of limestone, and dip away from the older rocks, their trend being parallel to the contact line. One of the best exposures occurs in the railroad cut just south of Stonypoint. In this region the sedimentary beds undoubtedly rest undisturbed on the older rocks and are true basal conglomerates. By this I do not mean to imply that they are necessarily the time equivalents of the basal conglomerates exposed in the lower part of the Stockton beds near Trenton and Stockton in New Jersey. They probably are somewhat younger than these, but they are the bottom beds in this vicinity and lie directly on the deeply eroded edges of older rocks. Unfortunately the broad waters of Haverstraw bay conceal many interesting stratigraphic points and forbid positive identification with beds farther south.

The boundary fault apparently does not terminate at the point where the Newark beds turned away from it. Both topography and geologic structure suggest that it continues northeastward across the Hudson river and along the valley of Peekskill Hollow creek north of Peekskill, but its extent in this direction has not been worked out.

Eastern border. The relations of the Newark beds to the older rocks on the north and northwest, have just been described in connection with the discussion of a fault along that border. On the east they are bordered by the Hudson. Across the river the rocks are slates, schists and gneisses. The junction of the Newark and pre-Newark beds lies somewhere in the bed of the river. The fact that the lowest observable strata always dip away from the older rocks, suggests that they rest directly on the latter. In New Jersey

well borings near the water front are reported to have penetrated the shales and entered crystalline rocks beneath. On the Delaware and in Pennsylvania the Newark beds are known to rest on the older rocks along the southeastern border. There is no reason for suspecting that the eastern border is marked by faults. On the contrary, all the evidence, meager as it is, points to the above conclusion, that here they rest normally though unconformably, on the older rocks.

Conditions of formation. In another paper[1] I have considered at some length the conditions under which these beds were formed. The following gives the main facts of that discussion.

The Newark beds of New York and New Jersey were deposited in a shallow estuary, whose shores were laid bare for considerable distances by the retreating tide and in which varying currents deposited coarse and fine materials. Shallow water conditions prevailed throughout the entire period of deposition. Since the beds are several thousand feet thick, subsidence of the estuary bottom took place simultaneously with the sedimentation. The material was derived from the adjoining land areas on the northwest and southeast. The comparative absence of crystalline pebbles and the great abundance of crystalline residuary material indicate that at the beginning of Newark time the rocks were very deeply disintegrated. The thickness of this mantle is best explained by supposing that the adjoining land was at or near base level. But the presence of pebbles several inches in diameter in the Newark beds indicates that during the period of deposition the streams had a velocity not consistent with streams on a peneplain. It is believed, therefore, that an elevation of the neighboring land areas marked the beginning of Newark time. The subsidence of the estuary bottom was probably complementary to the elevation of the adjoining areas. Stronger currents prevailed in the northern part of the estuary, so that the average of deposits was coarser there than farther south.

Along the northwestern shore the waves beat on cliffs of limestone and quartzite more than on those of gneiss or granite, and

[1]Annual report of the state geologist of New Jersey for 1897. p. 139-48.

so formed chiefly quartzite and limestone conglomerates. But the rivers drained large areas of deeply disintegrated crystalline rocks, and furnished from this source the bulk of the deposit over the sea floor. No evidence of glacial action can be found in connection with the massive conglomerate beds, which are undoubtedly the work of the waves and shore currents. They do not belong to any single horizon but are shoreward correlatives of the various shales of the middle of the estuary.

The deposition of the sedimentary beds was interrupted by at least three great lava flows, separated by long intervals of quiet during which sedimentation continued as before. These lava flows did not reach the New York area, but were restricted to New Jersey. At some period, probably after the surface flows, great sills of molten rock were intruded into the shales, and, if the Ladentown trap be the continuation of the Palisades sill, the greatest of them probably reached the surface in a small area at its northwestern extension.

The period of sedimentation was brought to a close by the elevation of the beds above sea level. This was accompanied by tilting and gentle folding but not by volcanic phenomena. The faulting is believed to have occurred at the same time. The nature of the elevating force is not well understood. The view which connects the tilting and faulting with widespread movements in the underlying rocks, by virtue of which the old surface was so deformed that the Newark sediments settled down on it as they could, seems best to accord with all the facts.

Since their elevation they have been greatly eroded. The constructional surface consequent on the faulting and folding has entirely disappeared. The region has been base-leveled once, elevated, parts of it base-leveled again and again elevated. Leaving out of account the comparatively slight modifications due chiefly to the glacial period, the present topography is the result of sub-aerial denudation. Thousands of feet of strata have been worn off from the present surface. The hills and ridges owe their hight solely to the fact that their rocks have better resisted the agent of denudation than have the rocks in the valleys.

SECTIONS OF THE FORMATIONS ALONG THE NORTHERN END OF THE HELDERBERG PLATEAU

Charles S. Prosser

CONTENTS

THE HELDERBERG ESCARPMENT, LOOKING SOUTH TOWARD THE INDIAN LADDER

INDIAN LADDER SECTION

Near the northern end of the Helderberg mountains, about south of Meadowdale, on the Susquehanna division of the Delaware and Hudson railroad, is the highway known as the Indian Ladder road and the only one climbing these precipitous cliffs between New Salem and Altamont. The Tentaculite and Pentamerus limestones form the prominent cliff which extends from New Salem around the northern end of the mountains to Altamont; but on the higher terraces and hills to the south the later formations are found, and their distribution is shown on the "Preliminary geologic map of Albany county, New York," by N. H. Darton.[1] Along the Indian Ladder road are exposures of the upper part of the Hudson formation, with magnificent cliffs of the Tentaculite and Pentamerus limestones; while to the east of south the succeeding hills show the later formations up to the lower part of the Hamilton, which forms the upper part of Signal station hill.[2] The section from Meadowdale to the top of Signal station hill is as follows:

		Feet
V A[1]	Covered from the station to a point near the base of the steep part of the hill on the Indian Ladder road.	310=310
A[2]	Partly covered; shales and thin sandstones of the Hudson river beds exposed along the road. At the top a massive sandstone 30 or more feet in thickness shown at the base of the cliff to the east of the road, which may be called the Indian Ladder cliff, at the waterfall. Mr Walcott reported "about 300 feet of the Hudson" in this section, and found specimens of Orthis testudinaria and Trinucleus concentricus.[3]	400=710

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[1] 15th ann. rep't N. Y. state geologist. 1895.

[2] The station was called Helderberg, and is 1823 feet A. T.—*Final results of the triangulation of the New York state survey.* 1887. p. iii

[3] Bul. geol. soc. Amer. 1890. 1:345.

		Feet
A3	Waterlime; best exposure near the base of the cliff at the waterfall. The measurements of different parts of the zone vary from $3\frac{3}{4}$ to $4\frac{3}{4}$ feet.	$4\frac{1}{2}=714\frac{1}{2}$
A4	Tentaculite; thin bedded limestone, forming lower part of vertical cliff. Some of the layers contain immense numbers of Tentaculites gyracanthus Eaton.	$31\frac{1}{2}=746$
A5	Transitional beds from the Tentaculite to the Pentamerus. Tentaculites gyracanthus Eaton has not been noticed in this zone, which is a little below the middle of the cliff, but Spirifer vanuxemi Hall reaches well toward its top.	$14\frac{1}{2}=760\frac{1}{2}$
A6	Pentamerus limestone; the massive strata forming the upper part of the vertical cliff. Beautifully shown in the cliff on the western side of the road, as may be seen in the accompanying picture, in which it is represented by the upper massive and most conspicuous part. The measurements along this cliff vary from 49 to 52 feet for the thickness of the Pentamerus.	$52=812\frac{1}{2}$
A7	Largely covered slope to the south of the cliff and east of the stream and road. In the field are various outcrops of the thicker beds of the shaly limestone, and in the edge of the woods the top of the Becraft limestone is shown. Much better outcrops of the shaly limestone, however, occur to the east of these woods in the field and along the western bank of a small stream, furnishing an excellent collecting place. The following species were obtained at this locality.	$160=972\frac{1}{2}$

1 Spirifer macropleurus (*Con.*) *Cast.* (c)
2 S. perlamellosus *Hall* (c)
3 S. cyclopterus *Hall* (a)
4 Leptaena rhomboidalis (*Wilckens*) *H. & C.* (c)

Plate 2

INDIAN LADDER. TENTACULITE LIMESTONE AT BASE, MASSIVE PENTAMERUS LIMESTONE ABOVE

5	Strophonella cavumbona (*Hall*) *H. & C.*	(rr)
6	Orthothetes woolworthanus (*Hall*) *H. & C.*	(rr)
7	Meristella laevis (*Van.*) *Whitfield*	(c)
8	Nucleospira ventricosa *Hall*	(r)
9	Parazyga deweyi (*Hall*) *H. & C.*	(rr)
10	Trematospira globosa *Hall*	(r)
11	Uncinulus vellicatus (*Hall*) *H. & C.*	(r)
12	Rhipidomella oblata (*Hall*) *H. & C.*	(r)
13	Cypricardinia lamellosa *Hall*	(rr)
14	Platyceras ventricosum *Con.*	(rr)
15	P. retrorsum *Hall* (?)	(rr)
16	Dalmanites pleuropteryx (*Green*)	(rr)
17	Favosites conicus *Hall*	(rr)
18	F. sphaericus *Hall*	(rr)
19	Streptelasma strictum *Hall*	(rr)

Above the house on the eastern side of the brook the top of the Becraft limestone, capped by the Oriskany sandstone, is well shown. The shaly limestone may also be seen to excellent advantage along the banks of Black creek to the north of the Indian Ladder road.

		Feet
A8	Oriskany sandstone occurs in the woods on top of the hill south of Indian Ladder cliff, where there are numerous very fossiliferous, more or less weathered blocks. Again it is well shown to the east of this hill on the ridge west of the house and brook mentioned above. Its thickness in these outcrops varies from 1 foot to 1 foot, 4 inches.	1=973½
A9	Esopus shale; finely exposed along the road to the east of the brook and house. Another excellent exposure occurs in the glen to the east of the eastern north and south road which on the plateau connects the Indian Ladder and New Salem roads.	100=1073½
A10	Schoharie grit; shown on a south road at the base of the light gray Onondaga limestone.	3½=1077

		Feet
A11	Onondaga limestone; well shown in the upper part of the terrace to the north of the New Salem road. The upper part of the formation forms the floor of this road for nearly two miles on the plateau.	98=1175
A12	Marcellus shale; black argillaceous shales exposed along the road up the hill to the south of the New Salem road and in the gullies on the northwestern side of the hill.	170=1345
A13	Covered.	20=1365
A14	Hamilton; arenaceous shales to thin sandstones at the base; but mainly shales to the top of Signal Station hill. Some specimens of the small Hamilton lamellibranchs, as Palaeoneilo constricta (Con.) Hall; Nucula bellistriata (Con.) Hall; Nuculites triqueter Con.; N. oblongatus Con. and others, are found in the shales in the upper part of this hill.	

ALTAMONT SECTION

XI C1	To the south of Altamont is a conspicuous point of the Helderbergs known as High point, where the general trend of the escarpment turns from a northwesterly to a westerly direction. The lower 646 feet of the point, according to the measurement of Ashburner,[1] from the Delaware and Hudson railroad station to the base of the Lower Helderberg limestones belongs in the upper part of the Hudson river formation. This thickness, added to the 2880 feet of shales and thin sandstones passed through in the Altamont well before reaching the top of the Trenton lime-	646=646

[1]The railroad station (formerly Knowersville) is 459 feet A. T., and Ashburner gave the altitude of the gas well's mouth as 510 feet A. T., and the base of the Lower Helderberg limestones as 595 feet vertically above the mouth of the well.—*Trans. Amer. inst. min. eng.* 16:951

Feet

stone, gives a thickness of 3475 feet for the Hudson river and Utica formations at this locality. Along the small brook in which the gas well is located there are exposures of the Hudson river formation, consisting of bluish to grayish argillaceous shales, with an occasional sandstone stratum; but the upper part of the zone is covered around the slope of High point.

C^2 In places at the base of the cliff 1 to 1½ feet of dark gray, impure, thin bedded limestone is exposed, which resembles the upper layers of the waterlime at Schoharie and Howe's cave, to which formation it is referred. 1=647

C^3 The lower part of the cliff is composed mainly of thin bedded, dark blue limestones, having the metallic ring of those composing the Tentaculite formation, and in the lower part are abundant specimens of Tentaculites gyracanthus (Eaton) Hall. By the side of the High point path there is 38 feet of this rather thin bedded limestone, in all of which Spirifer vanuxemi Hall is common, even to the top. The Tentaculites was not found in these upper layers. At this horizon there is a lithologic change; the upper beds are more massive, breaking with an irregular fracture, and Pentamerus (Sieberella) galeatus (Dal.) Hall occurs near their base, so that the line of division between the Tentaculite and Pentamerus limestones was considered to be represented here. The following species were collected at this place. 38=685

1 Tentaculites gyracanthus (*Eaton*) *Hall* (aa)
2 Spirifer vanuxemi *Hall* (a)
3 Leperditia alta (*Con.*) *Hall* (r)
4 Modiolopsis dubius *Hall* (rr)

5 (?) Tellinomya nucleiformis *Hall* (rr)
6 Stropheodonta varistriata (*Con.*) *Hall* (r)
7 Chaetetes (Monotrypella) arbusculus *Hall* (c)

C4 At the top of the High point cliff there is 27 feet of Pentamerus limestone, and a little to the south 10 feet more is shown. This limestone forms the top of the terrace, which extends nearly one mile to the south of the cliff before the shaly limestone is reached, but, on account of the heavy dip, it is not possible to give its entire thickness. 37=722

C5 On the partly covered slope south and west of the Pentamerus terrace are occasional ledges of the thicker layers of the shaly limestone and outcrops of the very much weathered and decomposed calcareous shales. These shales contain abundant fossils, and frequently on the surface of the slope many nearly perfect shells may be found. A hasty collection from such an exposure gave the following species:

1 Spirifer macropleurus (*Con.*) *Castelnau* (c)
2 S. perlamellosus *Hall* (c)
3 S. cyclopterus *Hall* (c)
4 Trematospira multistriata *Hall* (r)
5 T. globosa *Hall* (rr)
6 Leptaena rhomboidalis (*Wilckens*) *H. & C.* (c)
7 Eatonia medialis (*Van.*) *Hall* (a)
8 E. singularis (*Van.*) *Hall* (rr)
9 Meristella laevis (*Van.*) *Whitfield* (a)
10 Orthis (Dalmanella) subcarinata *Hall* (r)
11 O. (D.) perelegans *Hall* (rr)
12 O. (D.) planoconvexa *Hall* (r)
13 Orthothetes woolworthanus (*Hall*) *H. & C.* (rr)
14 Rhynchonella (Uncinulus) campbellana *Hall* (rr)
15 R. (U.) vellicata *Hall* (rr)
16 R. (U.) nucleolata *Hall* (rr)
17 Platyceras tenuiliratum *Hall* (rr)
18 P. gibbosum *Hall* (rr)

19 Streptelasma strictum *Hall* (rr)
20 Chaetetes colliculatus *Hall* (rr)
21 Favosites conicus *Hall* (rr)
22 Lingula centrilineata *Hall* (rr)
23 Favosites helderbergiae *Hall* (r)
24 Stropheodonta punctulifera (*Con.*) *Hall* (rr)

C⁶ At the top of the second terrace, about 1¾ miles southwest of High point, on the farm of Hiram Clickman, is a ledge of massive rock, frequently exposed about the edge of the hill, composed of the Becraft limestone and Oriskany sandstone. The northern end of the hill was partly covered. 10 feet of the Becraft limestone was found, but it is probably somewhat thicker, and the Oriskany sandstone rests immediately on top. The contact is finely shown at several places in the woods at this locality, the sandstone resting on the massive limestone, so that there are no beds of shaly limestone between these formations, as at Schoharie and Howe's cave. The limestone is light gray and rather crystalline, with the usual lithologic characters of the Becraft.

C⁷ The Oriskany sandstone is rather dark gray, weathering to a brownish color, quite calcareous, and contains many specimens of fossils. The thickness varies from 1¾ to 2 feet.

1 Rensselaeria ovoides (*Eaton*) *Hall* (c)
2 Spirifer arrectus *Hall* (c)
3 S. arenosus (*Con.*) *Hall* (c)
4 Eatonia peculiaris (*Con.*) *Hall* (r)
5 Rhipidomella musculosa (*Hall*) *H. & C.* (?) (r)
6 Metaplasia pyxidata (*Hall*) *H. & C.* (r)
7 Hipparionyx proximus *Van.* (r)
8 Meristella lata (*Hall*) *H. & C.* (rr)

There are frequent exposures of these two formations along the highway running southeast to the Indian Ladder road, and at various places one or the other forms the bed of the road for a distance of several rods.

About 3½ miles southwest of Altamont, on the road from Altamont to Knox, is a conspicuous ledge of the Pentamerus limestone (11 A³), to the east of the road, which at this

locality is very fossiliferous, and the weathering and fires have so decomposed parts of the massive cliff that it makes an excellent place for collecting. Along the road from Altamont there are alternating exposures of sandstones and shales, sandstones predominating, with a thickness of 635 feet by the barometer without allowing for the dip, which would increase the amount; then 210 feet are covered when this Pentamerus ledge is reached, 845 feet higher than Altamont. It is not clear whether the base of the Pentamerus is shown or not, but the Tentaculite is covered, and only 30 feet of the Pentamerus is exposed. The following species were collected at this place.

1	Sieberella galeatus (*Dal.*) *H. & C.*	(aa)
2	Atrypa reticularis (*Lin.*) *Dal.*	(a)
3	Strophonella punctulifera (*Con.*) *Hall*	(c)
4	Stropheodonta varistriata (*Con.*) *Hall*	(r)
5	Spirifer perlamellosus *Hall*	(r)
6	Uncinulus mutabilis (*Hall*) *H. & C.*	(r)
7	U. pyramidatus (*Hall*) *H. & C.*	(rr)

SECTION NEAR KNOX

About 4 miles southwest of Altamont and 1½ miles northeast of Knox, at a locality known as "the Rocks," are interesting exposures of the Helderberg limestones and, specially, of the Oriskany sandstone. This is also an excellent place for collecting Oriskany fossils, and the formation forms the bed of the Altamont-Knox highway for some distance. The following section begins on the lower road at the Armstrong house, near the foot of the hill, and extends to its top.

		Feet
XI B^1	Massive ledges of Pentamerus limestone. Probably the lower part of this zone is transitional to the Tentaculite limestone; but the latter is not shown at this place.	65=65
B^2	Mostly covered slope, with occasional exposures of shaly limestone. These shales are very fossiliferous, and many species may be obtained	95=160

Plate 3

in some of the small gullies, where the following were collected.

1	Spirifer macropleurus (*Con.*) *Castelnau*	(a)
2	S. perlamellosus *Hall*	(c)
3	S. cyclopterus *Hall*	(a)
4	Eatonia medialis (*Van.*) *Hall*	(c)
5	Leptaena rhomboidalis (*Wilckens*) *H. & C.*	(c)
6	Stropheodonta becki *Hall*	(rr)
7	Strophonella punctulifera (*Con.*) *Hall*	(r)
8	S. cavumbona (*Hall*) *H. & C.*	(rr)
9	Meristella laevis (*Van.*) *Whitfield*	(a)
10	Trematospira globosa *Hall*	(r)
11	T. multistriata *Hall*	(rr)
12	Dalmanella planoconvexa (*Hall*) *H. & C.*	(a)
13	D. subcarinata (*Hall*) *H. & C.*	(c)
14	D. perelegans (*Hall*) *H. & C.*	(rr)
15	Rhipidomella oblata (*Hall*) *H. & C.*	(r)
16	Atrypa reticularis (*Lin.*) *Dal.*	(rr)
17	Uncinulus vellicatus (*Hall*) *H. & C.*	(rr)
18	Stenoschisma formosa *Hall*	(rr)
19	Lingula centrilineata *Hall*	(rr)
20	Platyceras ventricosum *Con.*	(rr)
21	Streptelasma strictum *Hall*	(rr)

		Feet
B^3	Becraft limestone but a little below the Altamont-Knox road.	10=160
B^4	Very fossiliferous Oriskany sandstone underlying the road. On top of the sandstone, along the road are large numbers of impressions of Fucoides cauda-galli.	2+=162
B^5	Esopus shale, largely covered on the slope to the south of the road but showing fairly well in small gullies. ¼ of a mile to the east is a small quarry in the lower part of the shale.	83=245

B^6 Onondaga light gray limestone capping the hill. The dip on the face of this ledge is 2° s, 38° w.

SECTIONS NEAR GALLUPVILLE

To the south of Gallupville and the Foxkill is a high hill known as Mt Sagerwana, on which are various excellent exposures of the different formations; but unfortunately an accurate section has not been made of the hill, and the time spent in this study would well repay one.

X B^2 In the Beekman quarry south of Gallupville, to the east of the Mt Sagerwana road, is a good exposure of the Pentamerus limestone, which was formerly quarried and burned for lime. The rock is very fossiliferous, and it is an excellent place for collecting. In a comparatively short time the following species were obtained from this excavation.

1	Sieberella galeatus (*Dal.*) *H. & C.*	(aa)
2	Atrypa reticularis (*Lin.*) *Dal.*	(c)
3	Spirifer perlamellosus *Hall*	(r)
4	Stropheodonta varistriata (*Con.*) *Hall*	(c)
5	Strophonella punctulifera (*Con.*) *Hall*	(aa)
6	Uncinulus mutabilis (*Hall*) *H. & C.*	(c)
7	Lichenalia torta *Hall*	(rr)
8	Dalmanites micrurus (*Green*) *Hall*	(rr)
9	Dalmanites pleuropteryx (*Green*) *Hall*	(r)
10	Spirifer vanuxemi (*Van.*) *Hall*	(r)
11	Loxonema fitchi *Hall* (*?*)	(r)

About 170 feet higher than the Beekman quarry is a massive ledge of light gray, fossiliferous limestone, which shows on the Mt Sagerwana road and is also well exposed in the brook immediately west of the road. This is the Becraft limestone. The following species were collected at this locality:

1	Spirifer concinnus *Hall*	(c)
2	Camarotoechia ventricosa (*Hall*) *H. & C.*	(c)
3	Meristella princeps *Hall*	(c)
4	Atrypa reticularis (*Lin.*) *Dal.*	(c)
5	Rhynchonella (Uncinulus) campbellana *Hall*	(rr)
6	Orthis sp.	

A little farther up the brook is a ledge of Oriskany, which in this locality is a very dark gray to blackish quartzose sandstone. On the Mt Sagerwana road, about 395 feet higher than the Beekman quarry, are ledges of the Onondaga limestone, which are probably near the top of that formation. About 365 feet higher are ledges of Hamilton sandstones, on the northern slope of Mt Sagerwana, which contain some fossils. The formation continues to the top of the mountain, some 500 feet higher than the lower ledges of sandstone. By the side of the road, near its summit and the house of Eugene Miner, are argillaceous shales containing plenty of Hamilton fossils.

On the northern side of the Foxkill, below Shutter Corners, is a conspicuous ledge composed of the Tentaculite and Pentamerus limestones. This ledge was studied on the Couch farm, about ¾ of a mile below Shutter Corners, where the following section was made.

		Feet
X A^1	From the road at the Couch house to the base of the Tentaculite limestone the rocks are mostly covered. A small gully in the cliff north of the house shows the top of the waterlime and its contact with the Tentaculite.	210=210
A^2	Tentaculite limestone thin bedded and dark blue, with the characteristic lithology and fauna of this formation.	40=250

A^3 Pentamerus limestone, forming the upper and most massive part of the cliff.

A good view may be had of this cliff from the upper part of West mountain to the west of Schoharie village.

SCHOHARIE SECTIONS

To the west of Schoharie village and creek is a high hill known as West mountain, which has been a famous geologic region for more than half a century. A diagram of the mountain was published by Darton, on which the terraces and position of the various

geologic formations were represented.[1] A prominent limestone cliff begins about opposite the village and extends to the northern end of the hill opposite Central Bridge, where it turns to the west up the Cobleskill valley. This limestone escarpment may be distinctly seen by all passengers on the railroad from Schoharie junction to Schoharie. The rocks are better exposed in the middle and upper parts of this hill; therefore, in making a section of it, it is better to go down the creek about one mile from the Gebhard creek bridge.

		Feet
III B[1]	Mostly covered slope from the creek level to the base of the prominent cliff. About 100 feet below the base of the cliff some ledges of Hudson sandstone.	260=260
B[2]	Thin bedded, drab colored, impure limestones, which form the upper part of the waterlime.	10=270
B[3]	Dark blue, mainly thin bedded limestones, with the metallic ring of the Tentaculite limestone. From the top of the waterlime to the base of the massive limestone containing Pentamerus it is 44½ feet; but the upper 8 feet or more is somewhat transitional in lithology, for there are quite thick layers separated by thin shales. *Tentaculites* was not seen in the upper part of the formation; but *Spirifer vanuxemi* Hall occurs commonly in layers within 8 feet of the top.	44½=314½
B[4]	Massive, dark gray limestone, breaking with a rough surface, that forms the upper part of the cliff; the Pentamerus limestone. In the perpendicular wall of the cliff there is 27½ feet of the Pentamerus limestone; while the total thickness of the formation as measured at one place on the cliff is 50 feet, and at another 53 feet.	53=367½

[1] 13th an. rep't N. Y. state geologist. 1893 p. 227. More recently a sketch of this mountain has been given in Bull. N. Y. state museum no. 19, 1898 pl. 67.

		Feet
B^5	Shaly limestone, forming the middle covered slope of the hill.	128=495½
B^6	Massive light gray limestone, well-exposed in the cliff just below the house of George Acker. Becraft limestone which has a thickness of 15½ feet on the vertical face of the cliff, above which is apparently 5½ feet of massive limestone that ought to be referred to this formation.	21=516½
B^7	Upper shaly limestone, which is mostly covered; apparently 9¼ feet thick and possibly thicker.	9¼=525¾
B^8	Oriskany sandstone, which is best exposed in the yard by the house of George Acker. The upper part is a massive, dark gray to blackish, quartzose, very fossiliferous sandstone, showing usually a stratum from 1 to 2 feet thick. In the Acker yard, however, there are thinner sandstone layers below this stratum, which apparently belong in the Oriskany though on account of the unfavorable exposure, it was not possible to determine whether they contained fossils or not. These lower sandstones increase the thickness to 6¼ feet.	6¼(?)=532
B^9	Esopus shale, mostly covered, forming the upper covered slope of the hill.	121=653
B^{10}	Onondaga limestone, which forms the upper limestone cliff and top of the hill. 11 feet of the limestone is shown in the ledge; but below this the rock is covered, so that the Schoharie grit is not shown in this section.	56=709

In the above section the thickness of the Helderberg limestones is 256 feet, which is not much greater than that assigned to them by Darton, who reported that "at Schoharie [it is] not over 240 feet";[1] but the Esopus shale is some 50 feet thicker than stated by Darton.[2]

[1] 13th an. rep't N. Y. state geologist. 1893. p. 204.

[2] 13th an. rep't N. Y. state geologist. 1893. p. 203, where it is given as "70 feet at Schoharie."

The formations between the Hudson and the Helderberg limestones are better shown to the south of the Gebhard creek bridge and residence, where the following section was measured.

		Feet
III A^1	Clinton pyritiferous shales to creek level. Olive and bluish argillaceous shales in which are numerous nodules of iron pyrites. During the civil war a small mine was opened in this shale and worked for the iron pyrites.	19=19
A^2	Niagara ("Coralline") limestone; the lower and most massive layer is 4 feet, 5 inches; the middle one, 1 foot, 4 inches; and the top one 1 foot, 3 inches.	7=26
A^3	Covered slope, concealing the waterlime and lower part of the Tentaculite limestone.	56=82
A^4	Thin bedded, Tentaculite limestone.	11=93
A^5	Pentamerus massive limestone; the lower 21 feet partly covered, and the upper massive ledge, 22 feet thick, by the highway; but the entire thickness of the formation apparently not shown.	43=136

The base of the Niagara limestone gives a dip of 12 feet s, 20° w in a horizontal distance of 525 feet south along the creek bank from the old mine.

At "the Rocks" in the eastern part of Schoharie cemetery is quite an extensive quarry in the Tentaculite limestone. In the upper part of the quarry wall is the massive Pentamerus limestone, forming a cliff extending along the side of the hill for some distance. From the Tentaculite limestone in this quarry the following species were collected.

1 Tentaculites gyracanthus (*Eaton*) *Hall* (aa)
2 Spirifer vanuxemi *Hall* (a)
3 Chaetetes (Monotrypella) arbusculus *Hall* (c)
4 Beyrichia notata *Hall* (a)
5 Spirorbus laxus *Hall* (a)
6 Leperditia alta (*Con.*) *Hall* (a)

7	Tellinomya nucleiformis *Hall*	(r)
8	Megambonia aviculoidea *Hall*	(r)
9	Loxonema Fitchi *Hall*	(rr)
10	Modiolopsis (?) dubia *Hall*	(r)
11	Camarocrinus stellatus *Hall*	(r)

HOWE'S CAVE SECTIONS

Just west of the station on the northern side of the railroad track are large quarries in the Tentaculite and Pentamerus limestones. Below the track are several quarry openings in the lower part of the waterlime, part of which are abandoned, and still lower a quarry in the green Clinton shale, which is sold for gypsum. The following section is from the level of the Cobleskill to the top of the Pentamerus ledge in the upper quarry. The Hudson formation is not exposed along the Cobleskill at Howe's cave; but Hudson sandstones form a small fall in the creek more than one half the distance from Howe's cave to Central Bridge, and these shaly sandstones and shales are exposed in a railroad cut a little west of Central Bridge.

		Feet
VIII A[1]	Covered from the level of the Cobleskill at the suspension footbridge to the base of the green shales in the gypsum quarry.	32=32
A[2]	Clinton green argillaceous shales containing numerous nodules of iron pyrites. The lower 5½ feet are quite strongly crumpled, the folding showing very well on the wall of the quarry, while the upper layers are nearly horizontal, with only a little crumpling at their base. Farther west, at a point nearly below the old waterlime quarries, 33½ feet of Clinton shale is exposed, which extends to within 4 feet of the creek. Darton gave the thickness of the Clinton at this locality as "about 40 feet," and stated that "the Hudson river shales [are] exposed a short distance below."[1]	24=56

[1] 13th an. rep't state geologist. 1893. p. 218-19.

Feet

These shales are quarried, ground and sold for plaster; but several analyses of different specimens failed to reveal gypsum.

A^3 Niagara limestone. Dark gray, massive limestone in which Favosites niagarensis Hall and Stromatopora are conspicuous. In addition to these Spirifer sp. occurs rarely, which is the same as the one figured by Hall in *Paleontology of New York*, v. 2, pl. 74, fig. 8a-d, from the Coralline limestone [Niagara] at Schoharie (N. Y.) It was not identified specifically but considered as clearly allied to S. crispus (His.) Sow. In the cliff above the Clinton shale, is a massive stratum 4 feet, 4 inches in thickness. The total thickness is well shown by the roadside immediately west of the old cement quarries, where at the base is a massive stratum 4 feet, 1 inch thick, above which are thin bedded to somewhat shaly layers with a thickness of almost 3 feet. The Favosites niagarensis Hall occurs within 1 inch of the top of the shaly layers. Below the limestone is the upper part of the Clinton shales while above is the waterlime. This outcrop is very well shown by the picture in Darton's report[1], as is also the Niagara limestone at the top of the Clinton shale in the plaster quarry.[2] 7=63

A^4 Waterlime varying from dark to light gray and weathering to a buff color. Argillaceous and magnesian limestone which has thicker layers at the base and thinner bedded to shaly ones in the upper part. The top of the forma- 39=102

1 13th an. rep't state geologist. 1893. pl. 3.
2 13th an. rep't state geologist. 1893. pl. 4.

Plate 4

Howe's Cave. Tentaculite Limestone below, Pentamerus above

tion shows reticulated sun-cracks, and they are also nicely displayed on the floor of the quarry above the railroad track in its western part. According to Charles O. Schaeffer 7 feet of the lower waterlime is burned for hydraulic cement, of which 5½ feet is of first quality. Mr Schaeffer furnished the following analysis of a sample near the base.

Silica and insoluble matter	12.89
Carbonate of lime	55.17
Carbonate of magnesia	19.71
Iron and alumina	11.15
Moisture	.66

Another sample from near the top of the 7 feet of waterlime gave the following result.

Silica and insoluble matter	9.92
Carbonate of lime	68.32
Carbonate of magnesia	18.90

		Feet
A^5	Tentaculite limestone, dark blue, with 7 feet of massive layers at the base containing numerous specimens of Spirifer vanuxemi Hall and Tentaculites gyracanthus (Eaton) Hall (?) Modiolopsis (?) dubius Hall, Spirorbis laxus Hall and Stropheodonta varistriata (Con.) Hall occur less frequently. Typical Tentaculite limestone.	31½=133½
A^6	Transitional Tentaculite limestone, in which there are fairly thick layers separated by shaly ones. The lower layers contain numerous specimens of Spirifer vanuxemi Hall, while an occasional specimen of Tentaculites gyracanthus (Eaton) Hall was seen within 6 inches of the top. The complete fauna of this zone is as follows:	11=144½

1	Spirifer vanuxemi *Hall*	(a)
	(aa) in certain layers, specially in the lower part of the zone.	
2	Tentaculites gyracanthus (*Eaton*) *Hall*	(rr)
	Very near the top of this zone a few specimens only were seen.	
3	Stropheodonta varistriata (*Con.*) *Hall*	(c)
4	Beyrichia notata *Hall*	(c)
5	Spirorbis laxus *Hall*	(c)
6	Megambonia aviculoidea *Hall*	(rr)
7	Meristella laevis (*Van.*) *Whitf.*	(r)
8	Rhynchonella (Uncinulus) mutabilis *Hall*	(rr)
9	Chaetetes (Monotrypella) arbusculus *Hall*	(r)
10	Crinoid segments	(c)
11	Leperditia alta (*Con.*) *Hall*	(r)
12	Beyrichia trisulcata *Hall*	(r)

This fauna seems to show that the transitional beds below the base of the massive Pentamerus belong in the Tentaculite limestone.

	Feet
A[7] Pentamerus limestone; very massive, gray limestone, forming the upper part of the quarries, in which specimens of Sieberella galeatus (Dal.) H. & C. are very numerous. The junction of the Pentamerus and Tentaculite limestones is well shown at the western end of the cliff, where abundant specimens of Sieberella may be seen projecting from the weathered surface of the Pentamerus limestone.	23½=168

The following species were collected in this zone:

1	Sieberella galeatus (*Dal.*) *H. & C.*	(aa)
2	Rhynchonella semiplicata (*Con.*) *Hall*	(c)
3	Strophonella punctulifera (*Con.*) *Hall*	(c)
4	Spirifer perlamellosus *Hall*	(rr)
5	Chaetetes (Monotrypella) abruptus *Hall*	(r)
6	Favosites helderbergiae *Hall* (?)	(r)
7	Dalmanites micrurus (*Green*)	(rr)
8	Stropheodonta varistriata (*Con.*) *Hall*	(r)
9	Atrypa reticularis (*Lin.*) *Dal.*	(r)

Plate 5

10 Crinoid stems

The total thickness of the formation is not shown in these quarries. The Tentaculite capped by the lower part of the Pentamerus limestone, as seen in the eastern quarry, is very well shown in the accompanying picture. The Tentaculite and Pentamerus limestones are quarried and burned for quicklime, and they are also used in the manufacture of the artificial or portland cement now made by the Helderberg cement co. at this place. An analysis of the Tentaculite limestone reported by Mr Schaeffer is as follows:

Silica	1.48
Carbonate of lime	95.75

Another of the Pentamerus limestone gave the following result:

Silica	4.12
Carbonate of lime	93.68

Mr Schaeffer reported the dip as 23 inches to 100 feet about sw along the railroad track and 21 inches to 100 feet more nearly south in the tunnel. S. Norton, manager for the Helderberg cement co., gave the dip as 20 inches to 100 feet sw.

To the south of Howe's cave and Cobleskill creek is a steep hill, rising about 1000 feet above the level of the creek. This hill affords a fair section of the formations in this region, and the following gives their approximate thickness.

		Feet
8	B^1 Covered from the level of the Cobleskill to the base of the lowest massive limestone, which is apparently about at the junction of the Tentaculite and Pentamerus.	66=66
	B^2 Massive Pentamerus limestone, the lower ledge $22\frac{2}{3}$ feet thick; then a covered slope with a shattered ledge at the top.	53=119
	B^3 Shaly limestone; mostly covered slope with only a little of the limestone shown at the top of the formation.	95=214
	B^4 Becraft; massive, light gray limestone, forming a steep ledge from 15 to possibly 18 feet in thickness.	15=229

	Feet
B^5 Upper shaly limestone; rather thin bedded, light gray limestone in which there are fossils.	11=240
B^6 Oriskany sandstone, very fossiliferous; upper part very dark gray to blackish quartzose sandstone; lower part lighter gray. Well exposed, in contact with the subjacent shaly limestone, just west of an old house, where it is from 1½ to 2 feet thick.	2=242
B^7 Esopus black shales, which weather to a grayish color; mostly covered, but 8 feet showing in an excavation south of the old house and about 35 feet above their base.	100=342
B^8 Onondaga limestone; massive, light gray limestone forming low ledges to the level of the highway.	95=437
B^9 Marcellus and Hamilton formations from the highway to the top of the hill; but the slope is mostly covered. Fine pieces of Marcellus shale occur on the lower part of this slope, and thin Hamilton sandstones were seen toward the top of the hill.	528=965

PRELIMINARY REPORT ON THE GEOLOGY OF FRANKLIN COUNTY

Part 3

H. P. Cushing M. S.

CONTENTS

INTRODUCTION

The available maps of Franklin county are, except for the extreme northern part, so exceedingly inaccurate as effectually to prohibit detailed mapping and study. With these imperfect maps in hand the entire county has been rather hurriedly traversed, the only parts wholly unexamined being a comparatively small tract in the southeast corner around Mt Seward, in which tract there can be little question as to the character of the rocks, and the larger part of township 16, much of which is low and heavily covered with glacial deposits.

In 1897 I had the pleasure and advantage of the company of Prof. A. C. Gill, of Cornell university, in the field. He was desirous of obtaining some acquaintance with the region at first hand and nominally acted as assistant. I am under obligation to him for many of the facts recorded in this report, and desire to express here my hearty acknowledgments.

A part of the season of 1898 was spent in company with Prof. J. F. Kemp in work along the line between Essex and Franklin counties. This was the first opportunity afforded for comparing our respective results on the ground and was exceedingly helpful.

TOPOGRAPHY OF THE NORTHERN ADIRONDACKS

The following observations on the topography are made wholly unaided and unchecked by good maps, and are necessarily rather general. The county is divisible topographically into two parts whose junction is fairly abrupt. The one is the hilly or mountainous tract which occupies the southern and larger part of the county, and the other is a plain which slopes to somewhat the west of north, reaching its highest elevation at the Clinton county line.

The plain. The underlying rocks of this plain consist of only slightly inclined beds of sandstone and dolomitic limestone (Pots-

dam sandstone and Calciferous sandrock) which have been so overspread with glacial deposits, mostly to considerable depth, that the underlying rock but seldom protrudes through them, and exposures are rare except along the larger streams.

The boundary of this plain against the hilly tract is a somewhat irregular one. The ridges rise rather abruptly above the level of the plain, but the valleys between the ridges have the same level as the plain itself, the rather even surface of the glacial deposits extending unbroken up into the valleys, and the Potsdam sandstone frequently doing the same thing. Though the boundary is quite abrupt, the hills are low and well rounded and apparently pass under the Potsdam with the same character.

The present evenness of the plain is almost wholly due to the deposition of glacial materials on its surface. Prior to the Glacial period it was also a plain, though considerably more dissected by the streams than at present, that is the main stream valleys were wider and deeper, and tributaries were more abundant than now. Apparently at that time also the level of the plain corresponded with that of the valley bottoms, along its contact with the hilly tract. From the contact the plain slopes away to the north and northwest to the St Lawrence valley. The contact itself drops strongly in altitude going westward.

Hilly tract. The hills are composed of crystalline rocks which are much older than the Potsdam sandstone, and which formed the floor on which that rock was deposited. At that time the region consisted of low hills whose rocks were deeply weathered. It sank slowly beneath the sea, the depression commencing at the northeast and progressing slowly toward the south and west, as indicated by the decreasing thickness of the Potsdam in those directions, specially the former. It can not yet be certainly stated whether the paleozoic rocks were deposited over the whole of the Adirondack region or not, but there can be no question that they once extended far beyond their present limits. Their thickness in the district is unknown, but at the northern end of the Champlain valley, where they are thickest, the minimum value that can be assigned to them is 4000 feet, with the strong probability that

Plate 1

View looking northwest from Brookside farm, 3 miles east of Franklin Falls, showing the wide, drift-filled valley, and the hills toward Loon lake in the distance

at least 1000 feet must be added to that amount and likely even more. But at the time of their deposition the available evidence indicates that the relief of the region was not as pronounced as at present. The basal Potsdam is found running up to an elevation of 1750 feet in the northern Adirondacks. With the relief of the region as it is now the deposition of the minimum thickness of the paleozoic rocks assigned above on this Potsdam would leave none of the present peaks projecting above the general level.

Present character. At present the Adirondack region is constituted of ridge-like hills separated by valleys with usually a northeast and southwest trend. The hills are sometimes clustered into groups separated from one another by narrow passes, but these very rugged tracts are exceptional. More commonly the valley areas are considerable, and they often expand into quite wide parks. The hills rise to very varying altitudes but present always a general increase in hight going toward Mt Marcy and its neighboring peaks. The valley bottoms show the same increase in altitude in the same direction, though the amount of increase is less in their case, so that the hills tower higher above the valleys as Marcy is approached. The valleys are clogged with drift, in part morainic, in part deposited by overloaded glacial streams, and in part deposited in the beds of former lakes (*see* pl. 1). Were the drift cleared away, they would no longer be flat bottomed as at present but have an irregular, hummocky surface, as shown by the occasional protrusion of low ledges of rock above the drift, by the very uneven rock surface shown along those streams which have cut considerable valleys in the drift and by the rock-bound character of the shores of some of the lakes which still occupy valleys.

The hills are in general subdued in outline, instead of being steep and jagged. They show in the majority of cases low, gentle slopes to the north or northeast and steeper slopes to the south, often marked by a cliff at the top. These features are in large part due to glacial action. The low, northerly slopes appear to have been much evened off by the ice sheet, are covered by a

mantle of drift and show very infrequent rock outcrops. As the ice movement was to the southwest, the back slopes were, however, largely protected from wear. The cliffs are sometimes around the sides of coves produced by the action of local glaciers high up on the mountain sides and called cirques. At other times they are independent of such features, but in either case their origin seems referable to the same cause, namely that the glacier did not closely hug the mountain side, but that a gap (*bergschrund*) existed between the two, in which considerable range of daily temperature with alternate freezing and thawing would occur and produce rapid scaling off of the surface rock, the process being made much more efficacious by the almost universal jointing of the rocks. These joints have commonly a close approach to verticality, and the scaling off of the rocks along them gives rise to perpendicular cliffs.

By no means all the cliffs of the region have this origin however. Many steep-sided hills are found, where it seems strongly probable that the steep face is a fault scarp, though usually it is not possible to demonstrate the truth of this view.

The outer Adirondack hills on the north are mainly composed of red, orthoclase gneisses of unknown age and origin. These hills usually show typically the low, even north slope and somewhat steeper back slope (*see* pl. 2). These rocks are folded, and the folds pitch to the northward, sometimes only slightly, at others considerably. With this variation seems to come a variation in the steepness of the north slope of the hills, though ordinarily this is difficult of demonstration (pl. 3).

The anorthosite hills have usually steeper and somewhat more rugged outlines than have those of gneiss, though this is not necessarily the case. Undoubtedly the lack of foliation in these rocks has some influence in the matter.

Old base levels of erosion. The Adirondack region has been continuously above sea level since Lower Silurian times, an interval which represents a very considerable part of geologic time. During all these ages it has been subjected to unceasing wear, resulting in slow decrease in hight. The elapsed time has been suffi-

Plate 2

Birch hill, from Indian point, upper Chateaugay lake, looking east; showing the low, even north slope and steeper back slope of the hills which are composed of granitic gneiss

ciently long to permit the complete wearing down of the region, not only once but more likely a half-dozen times from an elevation such as the present one to the condition of a plain only moderately elevated above sea level. But the opposite to this process has also been in operation, and periods of quiet, during which the surface has suffered steady decrease in elevation through erosion, have alternated with intervals during which slow movements of the earth's crust have served to reelevate it. Where such intervals of quiet are sufficiently protracted the surface may be wholly worn down to a comparatively level plain known as a peneplain. Above its fairly level surface low, rounded hills composed of the more durable rocks may rise and are known as monadnocks.[1] If, after erosion has produced this result, the region undergoes uplift, the streams will commence to carve valleys in the elevated plain, and, by the deepening and widening of these valleys with the lapse of time, the old plain is carved into a hilly region, whose valley bottoms are at a new base level. The former low relief of the surface is indicated by the nearly uniform altitude to which the hill tops rise, so that the observer has merely to imagine the valleys refilled with the material which the streams have removed to obtain a clear mental picture of the surface as it was before the uplifting took place.

Two old base levels and two periods of uplift are clearly indicated in the northern Adirondacks, even without the aid of good maps and in spite of the difficulty of getting good views from most of the hills, due to the heavily-forested character of the country. One of the base levels is represented by the uneven line of the hilltops, excluding however many of the higher summits; and the other by the valley levels. The first period of uplift lowered the base level from the hill summits to the valley bottoms, and the second has produced a new base down toward which the streams are actively cutting but which they have not yet reached.

In the northern Adirondacks the hills rise to such diverse altitudes that the precise horizon of the old base which they represent has not been made out. The same difficulty is met when the

[1]Named from Mt Monadnock in New Hampshire, the type of the class.

new maps of Essex county are studied. These seem to show the possibility of separating the hills into two classes several hundred feet apart in altitude, but the distinction is not sharp, and all sorts of intermediate elevations occur. It is quite certain that, when this erosion period was terminated by an uplift, the uplifted surface was a quite hilly one, though it was also a surface of moderate slopes and subdued relief.

The valley bottoms owe their present level character to glacial deposits. Their present quite uniform altitudes indicate strongly a corresponding rather uniform altitude for the rock surface buried beneath the drift. Many of the valleys have resulted from the erosion of the crystalline limestones and associated gneisses, which are much the least resistant of all the Adirondack rocks. Other valleys occupy lines of fracture or faulting. Still others, however, are carved out of the same resistant rocks which constitute the hills.

The period of time during which the region rested at the new base was far less prolonged than the earlier period of rest. Some of the valleys are quite wide, others are narrow, but as a general average considerably less than half of the region has been cut down to the new level.

The last period of uplift occurred in comparatively recent times and must have been of considerable amount in order to give the valleys their present elevation above tide.

Tilting of base levels. Throughout most of St Lawrence county the hills are low, only rising a few hundred feet above the valleys, and their summits rise to approximately the same altitudes. Passing eastward into and across Franklin county, the hilltops, though of variable hight, reach progressively greater and greater elevations, till a north and south line is reached whose course coincides approximately with the boundary line between Franklin and Clinton counties and the prolongation of this line southward. Along this line are situated the highest elevations in the Adirondack region, culminating in the high peaks of the Marcy group, of which Marcy and McIntyre exceed 5000 feet, and several others nearly reach that elevation. To the north of these is

Plate 3

Furnace mountain from 1 mile south of Duane Center, looking west. Illustrates the steeper south slope of the hills. Both slopes are steeper than in the case of Birch hill, on account of the greater pitch of the gneiss

Whiteface, 4872 feet, only overtopped by four or five of the Marcy peaks. Farther north is Lyon mountain, 3809 feet, the highest points in Clinton county, though on the very outskirts of the hills. Still farther north, beyond the outer hills, the basal beds of the Potsdam sandstone constituting the edge of the high plain are found, resting against the gneisses at the greatest altitude reached by this plain north of the Adirondacks, and the gneisses have their greatest extension to the northward along the same line.

Passing still farther east, beyond this line, there is a tolerably rapid, often step-like, drop down to the level of Lake Champlain. This descent is produced by a series of meridional faults with down throw to the east, and the Champlain valley is a fault valley. There is also faulting to the west of the main axis of elevation but of a much less pronounced character, with the result that the descent in this direction is much more gradual.

In addition to this main north and south axis of elevation, there is also a minor east and west axis, the intersection of the two being in the Marcy neighborhood. The highest summits in Franklin county, Seward, Ampersand, Morris and Stony Creek Pond mountains, lie along this axis to the west of Marcy. To the eastward the drop is rapid, but high peaks occur in Elizabethtown along this line. The present configuration of the northern Adirondacks is then primarily due to dome-shaped uplifting, the Marcy group of peaks denoting the point of maximum uplift.

The Adirondack region is one of considerable elevation, and erosion goes forward quite rapidly, notwithstanding the heavy forest covering and the resistant character of most of the rocks. So pronounced an axis of elevation must be of comparatively recent formation, otherwise it could not possibly be so plainly marked a topographic feature. The prominence of many of the fault scarps is impressive evidence in the same direction; for the effect of long continued erosion is to wear away the raised block on the one side of the fault down the level of the dropped block on the other. Apparently the recent elevation of the region has been most largely effected by means of movements along the fault lines.

Both of the uplifts of the region which have been mentioned were of the same nature, being greatest in the Marcy vicinity and diminishing thence in all directions. This is shown by the fact that the two base levels are separated by greater and greater vertical distances in going toward Marcy from any direction. Unfortunately definite figures are lacking, but in general the valley bottoms range from 1500 to 2000 feet in altitude in the heart of the Adirondacks and are 1000 feet lower than that over a large part of St Lawrence county. The hills are only a few hundred feet above the valleys in that county, whereas they range from 1000 to 1500 feet above in Franklin county,[1] leaving the higher summits entirely out of the question.

The Potsdam sandstone furnishes a good measure of the amount of warping which the periphery of the Adirondack region has undergone about the north and south axis since that rock was deposited. On that axis the basal bed reaches an altitude of about 1400′ A. T. (the still higher Potsdam is found in depressions running back into the hills, and is not here considered). Going toward Lake Champlain, faults drop it down below the level of the lake, 101′ A. T., within a very short distance. Along Lake Champlain it lies mostly far below sea level, rocks many hundreds of feet higher in the scale being at the surface. Going westward across Franklin county and into St Lawrence, the altitude falls more slowly and steadily, so that in the neighborhood of Potsdam, about 50 miles distant, these beds lie from 600 to 800 feet lower than at their highest point. These figures represent the total amount of warping along this line since the deposition of the paleozoic rocks, subject to an unknown correction depending on the variations in altitude of the floor on which the deposition took place. That this floor was irregular is certain, that is, it consisted of low ridges and valleys, but these are mere local irregularities. That this surface was canted at this time there is no evidence.

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[1] It must be borne in mind that only the northern Adirondacks are under consideration. For a long distance to the southwest from Marcy the valley levels drop little, if any.

Drainage

Lakes. Though lakes are of frequent occurrence throughout the Adirondack region, there is a belt of territory in southern Franklin and northern Hamilton counties in which they are far more numerous than elsewhere. In Franklin county they can be enumerated by the hundred, and range from fairly large bodies of water, several miles long, down to the most insignificant of ponds. Very few data are available concerning them, and they would well repay the careful study which could not be given them in a hurried trip through the district during which the attention was centered on other problems.

The lakes are massed in greatest number along the watershed of the main streams, and do not differ greatly in altitude. This watershed is produced by the highest altitudes reached by the drift in the old valley bottoms and is to a certain degree independent of the main axis of the hills. The belt of abundant lakes at the headwaters of the streams is due to the high level dams formed by rock ledges, which lie across their courses farther down. The outlets of the lakes are in new channels and have encountered ledges of rock through which they must cut. Thus the level of Upper Saranac lake is maintained by the ledge of anorthosite over which its outlet pours at the Bartlett club house; Lower Saranac lake is held up by the ledges south of the village; Big Tupper lake has its outflow directly into the Raquette, and the level of that stream is determined by the rock ridge at Piercefield.

The larger lakes have rock-bound shores for the most part, and occupy the full width of the valley in which they lie. The lesser lakes may or may not have rocky shores, according as they lie in narrow or wide valleys, or whether the hollow in which they nestle lies in the center or toward the side of the valley.

The origins of these lakes are as various as the causes which produce irregularities in the drift surface. The larger lakes occupy portions of old stream valleys, which they fill from side to side, and are held in place usually by morainic dams across the valley. Some of the smaller lakes occupy kettle-holes in the

moraines; some occur in hollows in the surface produced by the uneven deposition of sand deltas by the overloaded streams of the period of withdrawal of the ice; others are due to the damming back of a valley's drainage by such sands across the valley; yet others may be due to other causes.

There is yet no evidence that any of them occupy rock basins, though it is by no means impossible that such may be the case. Big Tupper and Lower Saranac lakes may prove to belong to this category.

Streams. During the withdrawal of the Laurentide glacier from the northern Adirondacks, the preglacial stream courses cut in the valley base level were completely filled by the glacial deposits, while at the same time the irregular floor of the valley base itself was covered and evened by them. After the departure of the ice the courses of the streams were determined by the slope of these deposits, this slope being in large measure independent of the former channels, so that between the present and former courses there is considerable discrepancy. The slopes of the glacial deposits in the valleys were gentle, lakes occupied the hollows much more numerously than at present, and the new streams obtained steep grades only after they emerged from the hills on the slopes leading down to the Champlain or St Lawrence valleys. Their profile was convex, rather than concave, and so it remains to a large extent today, while in mature stream valleys the profile is concave.

The main streams of the region are of quite respectable size, and their fall is great. The Saranac river from Lower Saranac lake to Lake Champlain, in a course of about 75 miles by the river, has a fall of 1450 feet, or 20 feet to the mile. The Ausable from Lake Placid down, has a greater fall than the Saranac by 300 feet in a course from 5 to 10 miles shorter. The Racquette and St Regis rivers have a slope slightly less steep than that of the Saranac, but only slightly. These are very considerable slopes for streams of such size, and excavation of their beds is going on at a quite rapid rate. At first their courses were wholly in the unconsolidated drift deposits. These were quickly cut into, and soon the

tops of the rock ridges of the valley floors, which lay underneath the course of the stream where it was not over its old channel, were uncovered. The rapid down-cutting would be at once checked at these points, and the laborious process of sawing through the ridge substituted. But on the down stream side of the ridge the cutting in the drift would continue active, thereby producing a marked change in level at such points and causing a fall or rapid down the slope of the ridge. The eventual hight of this fall would mainly depend on the difference in altitude between the summit of the ridge and the summit of the next succeeding ridge uncovered by the stream below. By means of the slow cutting back of the fall a gorge would be formed below, which would correspond in depth with the hight of the fall. At the High falls of the Saranac in Clinton county, for example, the impressiveness of the fall and gorge are due to the fact that the next rock encountered by the river, at Cadyville 10 miles distant, is at an altitude 450 feet lower.

Up stream from a rock obstruction the drift could not be cut out to a greater depth than the level of the obstruction, except perhaps locally at the base of a fall. It would, however, be quickly worn out down to that level. By this process the stream courses would be divided into sections of slight declivity and of sluggish water, commencing and terminating at rapids over rock ridges. As soon as this stage has been reached, the rate at which erosion can go on becomes wholly dependent on the rapidity with which the stream can saw through the hard rock obstructions.

All the principal streams of the northern Adirondacks illustrate these general principles. Their headwaters are in chains of lakes, and their courses below consist of reaches of "stillwaters" or "levels", usually distinguished from one another locally by their lengths, as the 16 mile level, the 8 mile level and so on, which commence at the gorge below one rapid and terminate at the brink of the next. The divides between two lakes belonging to two different drainage systems are often of the most trivial character. Upper St Regis lake is less than a mile distant from Lake Clear, which belongs to the Saranac system, and the divide be-

tween the two is low and composed wholly of drift. Indian carry, between Upper Saranac lake and Stony creek pond belonging to the Racquette system, is less than a mile long, with a probable drift-filled channel between the two.

If the small brooks which cascade down the mountain sides into the lakes are left out of account, the main streams all have greater fall in their middle and lower reaches than in the upper portion of their courses. As time passes, this will become less and less true, and when the drainage becomes mature the reverse will be the case. When this stage is reached, the opportunities for wholesale changes in the present arrangement of the streams are sure to be improved.

The four principal north-flowing rivers of the Adirondacks, the Saranac, Ausable, Racquette and St Regis, rise in the heart of the region and flow, the first two northeastward into Lake Champlain, the others to the northwest into the St Lawrence, down the slopes of the north-south axis of uplift. As they thus diverge, other streams take their rise on the opposite sides of the divide to the northward, but their sources are at lower altitudes, and they are of less volume and are shorter than the first four. The Great Chazy, flowing northeast, and the Chateaugay, Salmon and Deer rivers to the northwest are the principal members of this group.

The Saranac is unique among these streams in that it crosses the main axis of elevation. Two main gaps cross this divide north of Mt Whiteface. The first is to the eastward of Franklin Falls, is due to the presence of the easily erodable rocks of the crystalline limestone series, and is now drift-filled and not occupied by any large stream, though seemingly the former channel of one. The other gap, through which the Saranac now goes, is at Unionfalls and has rock bottom in the river at 1400 feet, while the altitude of the low divide on the drift surface in the valley east of Franklin Falls is at 1700 feet.

The Saranac rises in Lake Clear, or rather in the large marsh some two miles in diameter, which lies to the northeast of that body of water and is merely its former extension in that direction,

now completely shallowed and filled by vegetable matter. It passes thence into Upper Saranac lake, Round lake and Lower Saranac lake and leaves the latter near the middle of its eastern side in a wholly post-glacial channel. At the rapids at Saranac village the river is only 6 miles distant from Lake Clear in an air line, while by water it is from 25 to 30 miles distant. Below the village the first considerable rapid is at Franklin Falls some 20 miles away, where the river falls 40 feet within the space of half a mile. In the 20 miles above it has fallen less than 100 feet, or only about 4 feet a mile. Below the falls it flows through a gorge half a mile long, with walls 100 feet high, which apparently marks the channel of a small preglacial stream, or else a low divide between two small streams. Below the gorge a wide marshy valley opens out, through which the river flows in a beautiful series of meanders. Heavy drift-filling turns it aside over the rock ledge in the gap at Unionfalls. At Clayburg, 8 miles below, it meets the north branch and turns abruptly into the larger valley occupied by that smaller stream. Turned aside, probably by depth of drift, the river encounters the ponderous rock ridge at the High falls, in which it has cut a very considerable gorge, which appears wholly post-glacial. The position of the preglacial channel hereabout has not been ascertained, a fairly continuous line of rock outcrops occurring to the northward and many appearing to the south of the present channel.

Beyond the High falls the valley is again broad and filled with drift. At Cadyville the river is once more out of its old channel, and has cut quite a gorge in the Potsdam sandstone at that point. From Cadyville to the mouth of the river at Plattsburg the fall is 400 feet and the distance 10 miles, giving a rate double the average fall of the stream, yet the bottom of the drift-filling is nowhere reached save at the pulp mill, 2 miles above Plattsburg, where a long but not deep cut through the Calciferous limestones has been made, and at Plattsburg itself.

The Racquette illustrates the same features. Its headwaters are in Racquette, Forked and Long lakes. In its northward course from Long lake it meets and is cutting through the ridge

at Racquette falls. Beyond, the valley is flat and marshy all the way to Piercefield, and the river runs in a terrific series of meanders. At the mouth of Stony creek it turns a sharp right angle to the west and flows in that direction to Tupper lake, receiving from the south the outflow from Follensby pond, Big Simonds pond and Tupper lake, all of these waters are held up by the level of the Racquette. From Long lake to Tupper lake is a distance of 20 miles by the valley, far more following the curves of the river, yet the total fall in that distance is but 70 feet, of which a large share is at Racquette falls. Beyond Tupper lake, or rather Piercefield, the river is swift and rapids are frequent.

The valley from Long lake to Stony creek is so exactly in line with the valley in which Upper Saranac lake lies that it seems almost certainly to represent a single line of preglacial drainage. Yet Indian carry between the two drainage systems, is over a rock ridge which seems to bar the way. Though there is probably a buried channel between the two, it must be constricted when compared with the width of the valley on each side.

The St Regis and Ausable rivers furnish equally good illustrations, though the Ausable differs from the rest in having its main source in the narrow, high level passes of the Marcy group, in small lakes which lie at altitudes from 400 to 600 feet above the lakes in which the others take their rise. Even Lake Placid, the only considerable lake on the Ausable drainage system, has a level 300 feet above the Saranac lakes. Furthermore it is not in the main line of the drainage, its outlet being merely tributary to the west branch of the Ausable.

The smaller rivers previously referred to, the Great Chazy, Chateaugay, Salmon and Deer, which drain the wedge-shaped tract of country between the diverging courses of the other and larger streams, differ from them in having their sources near the outskirts of the hills, so that the greater part of their course lies through the plain. Their present channels are determined by the slopes of that plain, so that on either side of the divide they flow in nearly parallel courses, their tributaries are few and small, and the interspaces are largely undrained. But their main fea-

tures are the same. Upper and Lower Chateaugay lakes on the Chateaugay, Chazy lake, in which the Great Chazy rises, and the many small ponds at the headwaters of the Salmon and Deer show the flat, poorly drained character of their upper reaches. Going downstream, frequent falls and rapids occur where the present channels are not precisely in line with the old ones. The Chateaugay is out of its former channel for a long distance, and has sawed a deep, narrow gorge into the Potsdam sandstone, second only in impressiveness to the Ausable chasm. The Salmon is cutting a gorge at Malone, and has a rock bottom, with rapids, at several points in Westville. While the still smaller streams have scraped away the drift down to bedrock in a few places, they have made no great progress in cutting into the rock.

PRECAMBRIAN ROCKS

The Precambrian rocks of Franklin county are wholly crystalline and have for the most part a foliated, or gneissoid structure. They consist in large part of rocks which are of unmistakable igneous orgin, comprising gabbroic, syenitic and granitic rocks; in small part of rocks of sedimentary origin, coarsely crystalline limestones associated with certain peculiar and characteristic schists and gneisses; in large part again of other, mostly finely granular, gneissoid rocks of unknown age and of uncertain, but probably of igneous origin. These rocks are in all respects similar to the Canadian rocks to the northward, from which they are separated by the interval in which the paleozoic rocks of the St Lawrence valley are at the surface. In the writer's judgment, they are to be as unhesitatingly classed with them as would be the case were the covering of later rocks to be swept away, so that they could be followed foot by foot across the intervening distance.

These Canadian rocks were subdivided into the fundamental gneiss and the Grenville series by Logan, the two constituting his Lower Laurentian. Both were supposed to consist largely of sedimentary rocks, and the former was regarded as the older. It

is more uniform in character than the Grenville series, lacking the limestones, quartzites and certain gneisses which appear largely in that series and being mainly composed of acid, orthoclase gneisses.[1]

In commencing work in the Adirondack region, this classification was taken for a working hypothesis. As work has progressed, the gneisses which it was thought might represent Logan's fundamental gneiss have been partially separated into their constituent elements, and in every case the separated element has been found to be of igneous origin, and to be intrusive into, and therefore younger than, the Grenville rocks. This has recently been strongly emphasized by Smyth, as a result of his work along the better exposed belts of the Grenville rocks on the west.[2] There still remains, however, a great body of gneiss of uncertain relationships, evidence respecting its age not being forthcoming as yet. Nor has its origin been demonstrated, though apparently no sedimentary rocks are represented in it, the gneisses throughout having the mineralogy and composition of igneous rocks. It may then be said that no rocks have been found in the northern Adirondacks which can be shown to be older than the Grenville series, but that in every case in which the relations have been made out, the adjacent rocks show intrusive contacts with the Grenville rocks. On the other hand, that is a sedimentary series and must have been laid down on some floor.

The latest conclusions of the Canadian geologists respecting the similar rocks in their territory are of great interest in this connection. In a recent report on the geology of the area to the north of Montreal, Prof. F. D. Adams says:[3]

> Whether all these gneisses really form a portion of the floor on which the Grenville series was deposited, since brought up by folding and erosion, and thus entitled to the appellation "fundamental gneiss", or whether they are intrusive masses, folded by the pressure to which the whole region has been subjected, can not be determined.

[1]Geology of Canada. 1863. p. 839.

[2]15th an. rep't N. Y. state geologist. 1895. 1:481-97.

[3]Geol. sur. Canada, new series. v. 8, pt J. p. 8-29.

In a somewhat more recent paper by Dr A. E. Barlow the relations between the "Laurentian" and the Grenville series are thus described:[1]

> The relations of these two members of the archaean in central Ontario suggest in the strongest manner that in the Grenville series we have a truly clastic group of strata which has slowly sunk down into, and have been invaded by, much greater volumes of the granites and gneisses of the Laurentian when these latter were in a plastic condition. . . The contact between the gneisses and granites of the Laurentian on the one hand, and the limestones and associated rocks of the Grenville series on the other, is, wherever examined, one of intrusion.

There are three possibilities in regard to the age of the undetermined gneisses of Franklin county, their igneous origin being admitted.

1 They may in whole or part represent a more ancient series than the Grenville.

2 They may represent a somewhat later series intrusive in the Grenville, but older than the great gabbro, syenite and granite intrusions.

3 They may represent thoroughly foliated phases of these later intrusions.

In the writer's present judgment they will be found to belong partly under 2 and partly under 3 but more specially the former.[2] All the later intrusions, so far as examined by the writer, while quite gneissoid, show at least rather massive cores, though the anorthosites are much more massive than the more acid rocks. But in northern Franklin county are wide areas of rather fine grained gneisses in which no such cores are visible. Furthermore these gneisses, and the Grenville rocks as well, are cut by numerous dikes of a peculiar and very characteristic, rusty-looking gabbro-diorite or norite diorite, while not a single case of such a dike has yet been seen cutting the anorthosites, nor the syenites and granites. A large dike of this character is found at the summit of Catamount mountain, in Clinton county, in a rock which resembles the later granite, though it has not been shown

[1] Barlow, A. E. Ottawa naturalist. Feb. 1899. 12: 205-17.

[2] It is by no means impossible that in part they belong under 1.

to be such. This is the only occurrence yet noted which may possibly invalidate the preceding statement. At the best this is only negative evidence, but it is desired to call attention to the possible light which these dikes may shed on the age of the gneisses.

Grenville series

Rocks which can be referred with certainty to the Grenville series are but sparingly shown in Franklin county, and occur in small disconnected patches instead of considerable belts.[1] But eight areas of sufficient size to appear on a small scale map have been noted, and of these six occur surrounded by rocks which are unquestionably igneous, and are not only of later date than the Grenville rocks but probably of later date than those gneisses whose origin is questionable. Inspection of the map shows that six of these eight patches have such position with respect to one another, that they seem to represent remnants of what were originally two continuous and parallel northeast and southwest belts, such as are now found in St Lawrence county infolded with other gneisses. Here in Franklin they have been invaded by great igneous intrusions, and all save these mere patches have disappeared. The contrasting conditions in the two counties can quite plausibly be explained by supposing that a greater erosion has taken place in Franklin county, so that rocks originally more deeply buried are now exposed at the surface there, whence it would follow that similar conditions now exist in St Lawrence at some distance below the surface. It should be said also that the fact of greater erosion in Franklin county is supported by independent evidence, instead of being a mere supposition brought forward for the purposes of this explanation.

Rocks of the Grenville series. The most striking and characteristic rocks of the Grenville series are the limestones. These are coarsely crystalline marbles which contain, even when purest, scales of graphite and phlogopite and grains of green pyroxene, and often apatite and titanite as well. Some very pure-looking beds prove to be composed of nearly equal parts of calcite and

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[1]See map accompanying this report.

Plate 4

Catamount mountain, Black Brook township, Clinton co., as seen from 2 miles to the west

white pyroxene, and it is by the alteration to serpentine of the latter mineral that the ophicalcites of the series are produced, as was long ago shown by Merrill.[1] These beds of limestone vary much in thickness in different places, but no evidence has been forthcoming in Franklin county to throw any light on the number of limestone beds or the possible thickness of the series.

Beds of pure limestone have been noted at only two localities in the county, at Franklin Falls and in the southern part of Malone township. At the old kiln near the Saranac river, 2 miles below Franklin Falls a massive bed outcrops, which is exposed for 100 yards across the strike, denoting a thickness of at least 150 feet if the dip is continuous throughout. As their outer surfaces are approached, the limestones become very impure, containing great quantities of green pyroxene and much quartz, with often scapolite and white pyroxene as well. Precisely similar beds are often found inclosed in gneisses and wholly apart from any large limestone bed. Good exposures of such are found by the roadside one half mile north of the bridge at Franklin Falls (*see* pl. 5). They weather rapidly on account of the leaching out of the calcite, and are among the most characteristic rocks of the series.

Quartzites have not been noted in Franklin county. Very quartzose gneisses occur which hold invariably a respectable percentage of orthoclase. An evenly granular, rapidly disintegrating, white gneiss which usually contains much graphite and consists essentially of quartz and white pyroxene, often with considerable pyrite, is a very common rock in this county, associated with the limestones, and is a decisive indication of the presence of the series in places where the limestones are lacking. Scapolite is a quite common mineral near contacts, and some of the quartz-white-pyroxene gneisses hold abundant scapolite. Graphite is a very important mineral in the diagnosis of this series, occurring in many of the gneisses as well as in the limestone. But some care is necessary in localities where exposures are meager, since this mineral also is found sparingly in some of the more acid igneous rocks. Sillimanite is another quite characteristic mineral.

1Merrill, G. P. Amer. jour. sci. Mar. 1889. 37: 189-91.

though it is not frequent in the Adirondacks in the writer's experience. Certain very garnetiferous, hornblende gneisses are very frequently associated with the limestone, though there are many other rocks rich in garnets, notably many gabbroic gneisses, so that such beds are by no means diagnostic of the series in the absence of others. In fact it is quite probable that much, if not all of such gneiss, when in association with the limestones, has been formed from gabbro intrusions.

These characteristic Grenville rocks are interbanded and interfolded with other gneisses which are precisely like rocks that occur over wide areas in which all trace of the Grenville rocks is absent. These are various, mostly fine grained, granitic, syenitic and gabbroic gneisses, so called since they have the mineralogy and composition of these igneous rocks, and have already been referred to as gneisses of doubtful age and origin. Some of these rocks associated with the limestones are so finely granular that they strongly resemble sandstones of various colors in the field, but the microscope always dispels this impression, absolutely no indication of clastic structure being visible, while the mineralogy is that of the igneous rocks above noted. In the writer's experience an abundance of these fine grained rocks is fairly indicative of the presence of the limestones near at hand, at least they have not been met with abundantly away from them. But, if this fineness of grain be a constant difference, it is the only one, and such rocks are provisionally regarded as the equivalents of the other gneisses, representing dikes and sheets injected into the Grenville rocks which have been given a parallel foliation and an interbedded appearance by subsequent metamorphism. Their more finely granular structure may perhaps be accounted for as a result of their proximity to the limestones, and to the yielding character of the latter under the severe pressures producing the metamorphism.

It is not to be supposed that anything like all the patches of the Grenville series are represented on the map.[1] The country

[1] The Malone and Waverly patches undoubtedly are of much greater extent than is indicated on the map. To the southwest of each is a wide area of flat country with no outcrops, indicating Grenville rocks below.

Plate 5

Impure limestones of Grenville series north of Franklin Falls.

has not been thoroughly traversed in the first place, and moreover the rocks are readily eroded and show only meagerly in outcrop. Three of the patches indicated on the map may have greater extent than there shown, as they are in line with areas of little relief in which no outcrops could be discovered.

The Franklin Falls, Saranac village and Follensby pond patches constitute the more southerly of the two northeast and southwest belts previously mentioned. It will be seen from the map that the depression occupied by Lower and Middle Saranac lakes (the latter usually called Round lake) is on the same line and with the same trend. Since no rock save anorthosite is exposed along these lakes, and the exposures are practically continuous around the shores, with numerous islands of the same rock, this concordance in trend may be a mere coincidence, but it at least suggests strongly that the depression may have been initiated by the presence of a continuous belt of the Grenville rocks along this line.

Doubtful gneisses

Rocks which must be referred to this group are exposed pretty continuously across the county from east to west, in the northern part of the Precambrian area, and as found near the Potsdam boundary have been briefly described in a preceding report.[1] Rocks differing widely in character, and not improbably considerably in age, are included in this category, which, as at present used, serves as a convenient receptacle in which to place all gneisses whose origin and relations are undetermined. In other words it is a temporary expedient in mapping, made necessary by the difficult character of the region. It is quite certain that, as present mapped, many small areas of the later granite are included, the term *later* being made use of simply to express the possibility of there having been two periods of granite intrusion, the earlier representatives being more gneissoid than the later. These areas are too small and with too indefinite boundaries to appear on a small scale map. On the assumption that these gneisses are of igneous origin, they are readily separated into

[1] Cushing H. P. 16th an. rep't N. Y. state geologist. 1896. p. 16–21.

varieties, corresponding to certain igneous rocks. There are thus granite, syenite, diorite and gabbro gneisses, together with plentiful intermediate varieties. Sometimes one variety will prevail alone over a considerable area, but more commonly in Franklin county two or more will occur in alternate bands, sometimes of very slight width, rendering the areal mapping of the different varieties an impossible task.

A very significant fact in its bearing on the origin of these gneisses is that in every case their mineralogy agrees precisely with that of certain igneous rocks, and the same holds true of their chemical composition in the few cases in which they have been chemically examined. While this is by no means decisive evidence in rocks so excessively metamorphosed, it seems improbable that beds of the extent and thickness of these should have been formed by deposition in water, with so little change in composition, in other words from material so largely unweathered. These rocks are thus sharply marked off from the characteristic Grenville rocks, concerning which neither of the above statements is true.[1]

These gneisses are characterized in the large way by a rather evenly granular structure and are usually fine grained, though with considerable variation in this respect. Some of them show traces of cataclastic structure, but this is the exception. Many of them perfectly resemble the more finely grained portions of rocks to be described later, which are regarded, both by the Canadian and New York geologists, as of undoubted igneous origin.

Orthoclase-quartz (granite) gneisses. The most widespread of the gneisses is a fine grained, red, acid rock composed essentially of alkali feldspars and quartz, with magnetite always present, and usually small amounts of hornblende or biotite. The feldspar is ordinarily microperthite or microcline, but some orthoclase is always present and it may predominate, while a little acid plagioclase is usually to be found in addition. Hornblende is the usual dark silicate, biotite being much less common.

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[1] Cf., Adams, F. D. Geol. sur. Canada. New series. v. 8, pt J. p. 35-85.

These rocks have at best only a very obscure foliation. They are cut by numerous quartz and pegmatite veins, and frequently become quite coarse themselves for a short distance.

Two types of structure are found which grade into one another. In the first type there are evidences of cataclastic structure. Larger feldspars occur, which become broken down at the edges, producing fragments whose origin from the parent fragment is often apparent. But no instances have been seen in which this structure is well marked, as in the case of the similar gneiss from Trembling mountain cited by Adams.[1] In much of the gneiss in fact, little or no sign of this structure is observable, but the feldspars are even sized, with highly irregular boundaries against one another, which often become very jagged and interpenetrate.

The quartz occurs largely in small idiomorphic individuals included in the feldspars, this being the case in the rocks with no sign of cataclastic structure, but only to a slight extent in the other type. The remaining quartz consists of fairly large individuals, always with rounded outlines, and usually of elongated, often greatly elongated, shape. These spindle-shaped quartzes are optical wholes, though showing pressure effects by an undulatory extinction which is not uniform over the whole but breaks up the crystal into several patches. It seems to the writer that the peculiar shape and character of the quartz is best explained as a result of a slow recrystallization, molecule by molecule, under the stresses of metamorphism, the optical anomalies shown resulting from slight subsequent strains applied to the rock.

In many parts of the region gneisses are found which are precisely like those here described except that they contain pyroxene in addition to the hornblende. Between these and other gneisses composed essentially of pyroxenes and feldspars, which are, next to the granitic gneisses, the most widespread rocks of this group, many intermediate varieties occur.

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[1] Adams, F. D. Geol. sur. Canada. New series. v. 8. pt J. p. 42.

Pyroxene gneisses, or granulites. These rocks are usually found interbanded with the granitic gneisses in Franklin county, the bands ranging from a few inches to many feet in thickness. Occasional large masses occur but are rather exceptional. They are gray to black, rarely red, in color and consist of pyroxene (both augite and hypersthene usually) and plagioclase and orthoclase feldspars as essential constituents, often with hornblende as well. Quartz is present at times. Petrographic descriptions of several of the varieties which these rocks present have been recently published by Adams, and need not be repeated in a report of this preliminary character.[1] The rocks are rather evenly granular, show little or no sign of cataclastic structure, and vary considerably in mineralogy from place to place.

These granulites are mainly confined to the northern part of the county, where they occur interbanded with orthoclase gneisses, or occasionally in rather large masses. In Malone and Belmont they are of gray color and consist of pyroxene (both hypersthene and aegirin-augite), orthoclase and a plagioclase which varies from oligoclase to andesine. If present at all, hornblende is in only slight amount. Sometimes the orthoclase, at others the plagioclase feldspar predominates, and each may appear to the exclusion of the other. Similar rocks are widespread throughout the Adirondack region.

In Brandon and Dickinson better foliated, black gneisses, composed essentially of hornblende and andesine feldspar, accompany the orthoclase gneisses, and the pyroxene granulites are scarce. These hornblende gneisses frequently contain augite or hypersthene or both, thus showing a gradation into the pyroxene rocks.

These gneisses are also extremely common in the Adirondacks. They have the mineralogy of diorites, or gabbro-diorites. They are absolutely not to be distinguished from hornblende gneisses of frequent occurrence which are unquestionable derivatives of the gabbros, described on a later page. In many localities such rocks are found containing an unchanged core of the igneous rock with characteristic ophitic structure, from which a gradual trans-

[1] Geol. sur. Canada. An. rep't, v. 8. pt J. p. 73–82.

ition may be traced within a few feet into the hornblende gneiss, which has been produced by the metamorphism of the latter. An excellent locality for such exposures is the west shore of Upper Chateaugay lake at the point where it narrows into the outlet. Another is a cut on the Northern New York railroad 2 miles south of St Regis Falls.

It is however the exception when the hornblende gneisses can be traced to a connection with the gabbros. The question at once arises whether there are hornblende gneisses of two distinct ages or they are all to be considered as derived from the gabbro. This question can not be answered as yet, though the writer rather inclines to the first alternative. Such gneisses are excellently shown around Dickinson Center, interbanded with the orthoclase gneisses in such fashion as to produce a strong impression that the latter represent granitic intrusions into the former, the whole drawn out and foliated by the metamorphism.

Later eruptives

To a considerable extent the Precambrian rocks exposed in Franklin county are younger than the Grenville rocks, and younger than most, at least, of the doubtful gneisses as well. These rocks are all of igneous origin, occurring as immense intrusive masses or as dikes, which show eruptive contacts against, and also include masses of the Grenville rocks and of the gneisses. Most of them have been metamorphosed and given a foliated structure, so that they are gneissoid, but frequently massive cores remain, into which the gneisses can be traced by a gradual transition. Quite similar gneisses also occur with no apparent massive core, and the recognition of such and their separation from similar phases of the earlier gneisses, as well as the accurate mapping of the boundaries of the intrusions themselves is often a matter of the greatest difficulty. These eruptives comprise rocks of the gabbro, syenite and granite families.

Anorthosites. The name anorthosite was given by F. D. Adams to eruptive rocks which occur widely in eastern Canada, are related to the gabbros and consist almost wholly of labradorite

feldspar. Similar rocks are extensively exposed in the eastern Adirondacks. They are at the surface over a large part of Essex county, and it has long been known that they extend into Franklin, an attempt to indicate their probable limits being made by Merrill in 1894.[1] One of the surprises of the recent field work in the county has been the very considerable area occupied by them, they running considerably beyond the limits assigned to them by Merrill from the very limited information at his command.

The anorthosites in the main are coarse to very coarse grained rocks consisting almost wholly of labradorite feldspar, whose large blue black crystals frequently reach a length of 3 inches and occasionally are a foot long or more. Not infrequently the crystals show the iridescent play of colors so often seen in this mineral, but nothing of the sort has been noted which will for a moment compare with the Labrador or Norway material. The extinction angles of the feldspar show that it is mostly labradorite though occasional angles of 30° and over indicate that more basic feldspars are also present in slight amounts. As accessory minerals ilmenite, apatite, titanite, garnet, augite, hypersthene, hornblende, biotite, pyrite, pyrrhotite, chalcopyrite and a little orthoclase and quartz have been noted, the two latter occurring only in minute patches in the sort of intimate intergrowth known as granophyr. Ilmenite, augite, hornblende and one of the three sulfids are the usual accompanying minerals, the others are only occasional and all are in slight quantity.

The structure is cataclastic, that is the rock has been subjected to great stresses, while deeply buried beneath other rocks since worn away, which have had the effect of more or less completely breaking down the large crystals into a multitude of small fragments, while at the same time the great pressure of the overlying rocks kept the rock at all times in an unyielding condition, instead of permitting it to be crushed to loose fragments. All grades of this occur from very coarsely crystalline varieties, with only a little granular material around the edges of the crystals, to those in which the granulation is quite complete, few or no large

[1]Merrill, F. J. H. Economic and geologic map of the state of New York.

crystals remaining. In general the extreme varieties are rare, most of the rock consisting of partially granulated material. There is also considerable variation in the fineness of the granulation itself in different parts of the rock, giving it a quite different appearance. The granulated portion is commonly greenish or greenish white in color, presenting a strong contrast to the blue black crystals.

As the peripheral portions of the anorthosite intrusions are approached, the dark silicate minerals become more abundant, so that the rock, while still very feldspathic, can not be regarded as wholly made up of that mineral. It occupies in fact, an intermediate position between typical anorthosite and gabbro, in which rock the augite plays as important a role as the labradorite, and may be called anorthosite-gabbro. The passage from one rock into the other is a gradual one, and has clearly resulted from a slight differentiation in the original intrusion during the process of cooling.

Along with this progressive change in composition often goes one in structure, the rock becoming on the whole less coarsely crystalline and usually somewhat gneissoid. The large labradorite crystals decrease in size and are less frequent. Not infrequently this change is carried so far that a distinct, rather fine grained gneiss results, of totally different appearance from the original rock, the only clue to its origin being the possibility of tracing it through intermediate varieties into the undoubted anorthosite, and the fact that it still contains occasional augen of dark blue labradorite. This rock weathers much more readily than does the anorthosite, and has a brown rusty look which causes it to appear more weathered than is really the case. In it hypersthene is often more abundant than augite, which is seldom the fact in the main mass of the intrusion, so that the rock is a norite rather than a gabbro. Except for the labradorite augen, which may ultimately disappear, these brown gneisses exactly resemble gneisses which belong with the syenites, shortly to be described, as well as certain gabbro gneisses which occur associated with the Grenville limestones. When anorthosite and

syenite areas adjoin, each showing these peripheral phases, it is an impossible matter sharply to delimit their boundaries in mapping.

In some cases hypersthene, augite and garnet, with or without biotite and hornblende, constitute such a large portion of these peripheral rocks that they become true gabbros or norites in composition, so that one can pass from anorthosite to gabbro in going from the center to the exterior of a single intrusive mass.

Wherever anorthosite is the surface rock, exposures abound. As indicated on the accompanying map, a large area in the southeastern part of the county is wholly occupied by this rock. It is cut by numerous dikes, later to be considered, but these are almost without exception of no great size. It appears in a series of east and west ridges, which attain high altitudes in the extreme southeast with Mt Seward and Ampersand mount as the culminating peaks; in the lake belt the relief is but slight, the majority of the ridges not being more than one or two hundred feet above the water surface, with the comparatively low peaks of Boot Bay and Long Pond mountains representing the highest points; to the west of the lake belt the extent of the rock is not great, but the ridges are higher, culminating in St Regis, Jenkins and Ore-bed mountains. Abundant exposures occur about the Saranac and St Regis lakes and the host of ponds in the lake belt, the trend of the ridges being at right angles to the trend of the larger lakes, and resulting in the production of their extremely irregular shore lines. Exposures are so much more abundant, than where the gneisses or the Grenville rocks are at the surface, that the passage from the one to the other may be inferred from this alone where outcrops are not forthcoming.

The northern boundary of the anorthosite is very plain, unmistakable anorthositic rocks adjoining closely rocks of totally different character. On the south and southwest this is not the case, the rock fading out into the augen gneiss already described. This change is well shown by the exposures along the Racquette river going either west or south from the big bend at Axton, where anorthosite-gabbro is exposed. Going west, the last of the augen

gneiss is found from 2 to 3 miles below Tromblee's and is found well exposed along Follensby pond. Going south, the last of it is found in the gorge at Racquette falls. In all these places considerable fairly coarse anorthosite-gabbro is found along with the granular gneiss, and the only explanation that will fit the phenomena in the writer's judgment is that the augen gneiss is derived from the coarser rock by crushing.

Whiteface type of anorthosite. Mt Whiteface in Essex county is composed of a gabbroic rock of peculiar appearance, which has been dubbed the Whiteface type by Kemp, to distinguish it from the usual rock of the Mt Marcy type.[1] This rock gets over the border into Franklin county at Franklin Falls, and also runs into the corner of Clinton on Catamount and Wilmington mountains.

This rock differs from the ordinary anorthosite in many respects. It is usually completely granulated, though occasional feldspar augen indicate a cataclastic structure. The feldspar is white in color, the green tinge of the granulated feldspar in the usual variety not appearing. The dark silicates are more prominent, and the rock is usually markedly gneissoid. They are irregularly distributed, parts of the rock being nearly free from, and parts heavily charged with them. The white color, even when the rock is weathered, is in strong contrast to the green and rusty brown shades of the gneissoid parts of the other rock.

Under the microscope the chief difference is found in the predominance of hornblende among the ferro-magnesian silicates. Next in abundance comes a green augite. No hypersthene has been noted. The feldspar is mostly labradorite, as shown by maximum extinctions of from 22° to 27° from the albite twining plane in sections which extinguish equally on both sides. The accessory minerals are the same as in the ordinary anorthosite, iron ores, zircon, apatite, titanite, garnet, biotite and sometimes a little quartz. The structure is cataclastic and the feldspars show marked strain phenomena, the twining lamellae being bent, often pinched out or else largely disappearing. In many slides

[1] Kemp, J. F. 15th an. rep't N. Y. state geologist. 1895. pt 1. p. 587. Ibid. Bull. N. Y. state museum no. 21. 5:57.

unstriated feldspar abounds but is regarded as labradorite with all appearance of twining destroyed by strain.

The localized occurrence of this rock, together with its constant peculiarities, disposes the writer to consider it as a separate intrusion, probably slightly later than the ordinary anorthosite in time. The evidence for or against this view can be obtained only from Essex county, if there. In Franklin county the only exposures occur in the vicinity of Franklin Falls, the best being along the river. Grenville limestones lie close at hand to the north and east, and, as they are approached, the rock becomes rapidly more basic, passing into a gabbro-gneiss of dark color, with a foliation parallel to that of the succeeding Grenville rocks.

On the west end of Catamount mount, 5 miles east of Franklin Falls, in Clinton county, this Whiteface type is exposed, surrounded on the north and east by the same gabbroic gneiss as at Franklin Falls, this being followed by a red, granitic gneiss toward the top of the mountain, with no contacts showing so far as the writer has been able to discover. In this gabbro-gneiss occasional augen of blue labradorite appear; in one place a considerable face of rock like the Marcy type of anorthosite-gabbro was seen, and near at hand, inclosed in a rotten brown gneiss, was an unmistakable inclusion of ordinary anorthosite with numerous blue labradorite augen, some of quite large size and iridescent. The locality is very suggestive, but unfortunately the precise nature of the inclosing rock is obscure on account of its decomposed condition. It is connected with, and seems to be a phase of, the dark gabbro-gneiss rather than connected with the main mass of the typical Whiteface anorthosite, and the question of the relationship of this gabbro-gneiss is still an open one. From its distribution around the edge of the Whiteface anorthosite it would seem to represent merely a differentiation phase of that rock, which would then be younger than the ordinary anorthosite. It strongly resembles the gabbros whose consideration follows, and may belong with them, in which case its apparent close relationship with the Whiteface anorthosite may have a much broader significance. Or the inclusion may not be an inclusion

at all, but of the nature of a mammoth *auge*, an uncrushed portion of the original rock whose granulation and stretching produced the gneiss. The brown gneiss and anorthosite taken together furnish a combination which resembles extraordinarily some of the augen gneiss exposures along the Racquette already described. We can not answer these queries at present. In rocks so metamorphosed and changed the precise nature of such exposures as these is seldom clear.

Syenites. While the presence of great bodies of gabbroic intrusive rocks in the Adirondacks has long been known, it is only very recently that evidence of similar intrusions of syenitic rocks has been forthcoming.[1] This is for the simple reason that the rock is by no means so easy of discrimination, being highly variable, usually gneissoid, weathering much more readily, and in weathered condition closely resembling other rocks of apparently wholly different relationships.

These rocks are widely exposed in Franklin county. When fresh they are of green or greenish gray shades, of considerable variation in grain, though never presenting very coarse phases comparable to the anorthosites, and usually of markedly gneissoid, or else of linear structure. While there is often evidence of cataclastic structure, it is exceptional that any considerable feldspar augen remain, and usually considerable recrystallization has taken place. The contrast with the anorthosites in these respects is so marked that some explanation must be sought in an original difference between the two rocks, as they are of about the same age and have therefore been metamorphosed under similar conditions. It is thought to be due simply to an original difference in coarseness of crystallization, the excessive coarseness of the anorthosites rendering complete granulation a matter of much greater difficulty.

As is the case with all the intrusive rocks of the district, comparatively massive cores of less changed rock are of not uncommon occurrence. The most foliated rocks are those with con-

[1] Smyth, C. H., jr. Bul. geol. soc. Amer. 6: 271–74.
—— 17th an. rep't N. Y. state geologist. 1897. p. 471–486.
Cushing, H. P. Bul. geol. soc. Amer. 10: 177–92

siderable content of the black, ferro-magnesian silicates. In the more quartzose rocks these are present in only slight quantity, and instead of foliation a linear structure appears, due to the drawn out, spindle form which the quartz assumes.

These rocks rapidly undergo a color change from green to brown on exposure to the weather, though greenish nodules may frequently be found in the brown rocks. This color change may occur without perceptibly impairing the freshness of the constituent minerals. Usually however the hypersthene (or bronzite), and often too the augite are found to be more or less decayed in the brown rocks. These brown gneisses cover a wide area in Franklin county, and, while in part they are easily recognizable as belonging with the syenites, in other part they are puzzling, and may or may not belong here. It thus becomes a very difficult matter to determine the precise limits of the main intrusions and in the case of smaller patches to determine at all whether the rocks belong in this group. Furthermore, the ground has not been exhaustively studied, so that the limits of these rocks as shown on the map are in a high degree provisional. The main areas are indicated, but there is question as to their precise extent. In general doubtful varieties occurring in close association with undoubted syenites have been classed with them; those with no such association have not been so mapped.

There is much local variation in structure and composition in these rocks, reminding one of the similar variations which are so characteristic of the gabbro group. This local variation hampers the endeavor to determine whether differentiation has taken place in the main intrusions so that no certainty has been reached in regard to it. It is however believed that such has been the case and that the associated granites will be found more massed toward the centers of the intrusions. All intermediate stages between granite and syenite may be found so that there is evidently a passage of one rock into the other. These granites are either red or green in color, and while very quartzose and poor in dark silicates, these are the same as appear in the syenites, and the quartz has the same spindle form.

The most common rock is a quartz-augite-syenite, composed essentially of microperthitic feldspar (orthoclase and albite or oligoclase), augite, hypersthene or bronzite and quartz. Hornblende is almost always present as well, and in a considerable portion of the rock comes to exceed the augite in quantity. In these hornblendic varieties the hypersthene is usually absent, and ordinarily some biotite appears. Quartz is usually present, as it is in the augite syenite. The two varieties shade into one another with facility.

Accessory minerals are zircon, apatite, magnetite, pyrite, garnet, titanite, allanite, and oligoclase feldspar. Garnet occurs but sparingly and, so far as noted, only as corrosion rims around magnetite. Its scarcity is in strong contrast to its abundance in the gabbro rocks. On the other hand titanite, rare in the gabbros and anorthosites, is here quite characteristic, while the rare allanite does not occur in them at all so far as noted.

The green augite and the bronzite (or hypersthene more rarely) are often minutely intergrown in thin parallel plates, and, while the minerals themselves and the hornblende as well are closely like the same minerals in the gabbro rocks, these intergrowths have not been observed in them and seem quite characteristic of the augite syenites.

The greater part of the feldspar consists of the minute intergrowth of orthoclase and an acid plagioclase to which the name "microperthite" is applied. The plagioclase is usually albite. A little oligoclase is usually present in addition to the microperthite. No microperthites with oligoclase cores, similar to those described by Smyth in the augite syenite at Diana, in Lewis county, have been seen in Franklin county.

Quartz seems to be present in all the syenites of the county, though in the more basic varieties it is in only slight amount and wholly in the form of small inclusions in the feldspars, such as are frequently found in the feldspars of the entire group. But, in addition, in the more acid members is much coarse quartz, which in a large part of the rock assumes the elongated, spindle form already alluded to.

There is no question that a more detailed investigation of these rocks will necessitate their subdivision into a number of minor types, some of which may be sharply marked off from one another and represent wholly separate intrusions. Pending such investigation, it is unwise to attempt subdivision. It may be said that these rocks vary exceedingly from place to place, both in composition and in structure, often with great rapidity, recalling the gabbros in this respect. In part they are granites, in much larger part augite or hornblende syenites, both with and without quartz. So far as they have been carefully studied, all the syenites of Franklin county belong to the type of these rocks comprised under Brögger's name akerite.

The main areas of syenite in the county are indicated on the accompanying map, and may be called the Loon lake, Tupper lake, St Regis river and Salmon river areas. The Loon lake area may prove to fall into two distinct areas on farther study, the second of which may be called the Saranac river area, excellent exposures appearing along the river from Franklin Falls up nearly to Saranac.

Extending northward from Franklin Falls and thence along Alder brook as far as the north branch of the Saranac, is a chain of low hills of a peculiar, coarse, brown gneiss, which is regarded as belonging to the augite syenites, though so weathered that it is almost impossible to get fresh material. In the one or two places from which such has been obtained, as from the roadside near Alderbrook postoffice, it is not quite certain that it is of the same rock; but, if so, it is augite syenite. These brown rocks vary from place to place quite as the ordinary syenite does, and differ mainly in the less pronounced spindle form of the quartz when present. The hills formed of this rock are low but very steep sided, producing an unmistakable topography from which the character of the rock may be predicted with certainty (*see* pl. 6). The rock has cataclastic structure, is certainly igneous, and is a syenite, in large part a quartz-augite-syenite, though often with much hornblende.

Plate 6

A small mass of an ordinary quartzose augite syenite, quite like much of the rock around Loon lake, occurs near Lower Chateaugay lake in Belmont township. Quite likely similar small intrusions will be found elsewhere when the county is more carefully surveyed.

The precise age of these syenite intrusions is not yet known. At Loon lake they cut the Grenville rocks,[1] and elsewhere the doubtful gneisses, and are hence younger than either. The gabbros to be next described have been reported by Smyth as cutting the Diana augite syenite in Lewis county.[2] The syenite is therefore older than these gabbros. The unsettled point concerns their relation to the anorthosites. As to this, evidence is so far lacking in Franklin county, and so far as the writer is aware in the rest of the Adirondacks as well. The areal distribution of the two in Essex and Franklin counties is however so involved, that localities will certainly be found in which this important evidence will be forthcoming. The main difficulty arises from the puzzling peripheral phases which both rocks exhibit.[3]

Gabbros. These are basic and dark colored, often black, rocks of quite variable composition and structure. Though their areal extent is not great, they are of common occurrence throughout the Adirondacks, and have been more frequently and exhaustively described than any of the other igneous rocks of the region.[4]

As seen in Franklin county these gabbros occur either as dikes or as small intrusive bosses. They are wholly distinct from the gabbro-gneisses which occur as border facies of the anorthosites. The dikes are the more common, but the bosses are by no means infrequent, and beyond doubt many more remain to be discovered.

The dikes are almost without exception very fine grained, black

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[1] Cushing, H. P. Bul. geol. soc. Amer. 10:185.
[2] Smyth, C. H. jr. Bul. geol. soc. Amer. 6:283.
[3] Kemp, J. F. Bul. N. Y. state museum no. 21. 1898. 5:283.
[4] Kemp. J. F. Amer. jour. sci. Aug. 1892. 44:109-14.
—— Bul. geol. soc. Amer. 5:213-24.
Smyth, C. H. jr. Amer. jour. sci. 1894. 48:54-65.
—— Bul. geol. soc. Amer. 6:268-83.
Amer. jour. sci., 4th ser. 1:273-81.

rocks. The border parts of the bosses are quite similar, but centrally they are much coarser, are more feldspathic, are of gray color spotted with black, and their characteristic ophitic structure and corrosion rims are at once evident to the eye.

As a result of the metamorphism which they have undergone, these gabbros are in large part converted into amphibolite gneisses. Most of the bosses show a comparatively unchanged core, from which a regular gradation in structure and mineral content into the amphibolite can be traced. In some the conversion is almost complete, but these usually furnish material from their central portions which exhibits traces of the original minerals and structure in thin section. Still others show no such traces, and these last are, with our present knowledge, absolutely not to be distinguished from other amphibolite gneisses which have been provisionally classed with the doubtful gneisses and already described. Quite similar rocks occur also in close association with the crystalline limestones and graphitic gneisses of the Grenville series. The writer regards them all as metamorphosed igneous rocks, either gabbro or some related rock, but believes these last to be much older than the gabbros immediately under discussion. Certain small areas of amphibolite are met with, however, which can not be classified with certainty with either.

Much the same phenomena are presented by the dikes. These show considerable variation in thickness but are mostly under 30 feet and often only a foot or two. Some of them have their original character in large part preserved, others are wholly changed into amphibolite, yet others show intermediate stages. The wholly changed dikes are so like other schistose, amphibolite dikes which occur all over the Adirondack region that the writer is not certain that they are not the same, though the ordinary rusty appearance of the latter, coupled with the fact that they have not been noted cutting any of the certain later eruptives (anorthosites and syenites) disposes him to regard them as of different and earlier age. Their mineralogy is precisely the same, except that garnet is not so abundant as it usually is in the other rock.

As far as can be judged from the less metamorphosed portions, these gabbros show a similarity in mineral content and in structure which is unusual in gabbroic rocks. The essential original minerals are in every case, a plagioclase feldspar (usually labradorite), augite and magnetite (always titaniferous). In some of the rocks hypersthene must be added to this list, but in these it seldom equals the augite in amount, so that norite, an intrusive rock constituted essentially of labradorite feldspar and hypersthene, is rare in Franklin county. In all cases in which the original structure has been preserved, it is found to be ophitic, that is the feldspar is in long, lath-shaped crystals separated by, and partially embedded in, the large, stout prisms of the augite. These primary feldspars and augites invariably hold a multitude of minute, microscopic inclusions, the augite specially containing them in such numbers that in thin section it would often be impossible to make out the color of the mineral, were it not for the fact that a narrow outer zone is comparatively free from them. These inclusions in the augite are mainly opaque under high powers and are probably of magnetite or ilmenite. The feldspar inclusions are for the most part small augites arranged linearly parallel to the long axis of the laths.

From the extinction angles shown by the feldspars in the various slides it is quite certain that they show a range from andesin to anorthite in the different specimens, with labradorite the more usual one. The augite is of an exceedingly pale gray green shade, nearly colorless in very thin sections.

In addition to the foregoing, even the least metamorphosed rocks show much rather finely granular material, either in clumps or in trains, consisting mainly of garnet, augite, hypersthene or bronzite, labradorite and hornblende, to which biotite is sometimes added. These are all in equi-dimensional grains, and were forming at the same time, as none of them show crystal boundaries. In the more fully metamorphosed rock this granular material increases till it comes to constitute the whole, all traces of the original minerals having disappeared. In some slides the large, original augites can be seen trailing out into this granular

material, which has evidently been produced at their expense. The feldspars occasionally show the same thing. It is however in no sense a cataclastic structure, as the grains are not mere shattered fragments of the larger crystals but consist of all the minerals mentioned above. The process is one of recrystallization and wholly owing to the metamorphism. In these granular mixtures the augite, hypersthene and labradorite differ from the primary minerals in being wholly free from the inclusions with which they are packed.

In the main, recrystallization has commenced at the contacts between the feldspar and augite, or feldspar and magnetite, and such minerals as garnet which were not in the original rock have resulted from the incorporation of material from each of the adjoining minerals. In several slides garnets of quite large size, fully as large as any in the slide, are found as inclusions in the primary feldspars, and at times augite and hypersthene are found with them. In an unmetamorphosed rock their occurrence in such situation would be proof of their primary origin, as they must have been formed before the feldspar in order to be so included; but that can hardly be the case here, and the writer is disposed to account for them in the same way as before, the augite or magnetite necessary for their formation perhaps being furnished by the inclusions of these minerals with which the feldspar is so heavily stocked. Often a narrow zone of the feldspar around these included garnets has been completely freed from these inclusions, which is corroborative evidence of the truth of this explanation so far as it goes. It does not help to explain why such inclusions of garnet are not more often met with, the small ones being always present, but the same difficulty will apply in a less degree to the entire rock, as garnet is by no means found along all the contacts between the minerals concerned. Undoubtedly percolating water played a large part in the process, and the garnet inclusions in the feldspars are always on the line of cleavage cracks.

Two different varieties of hornblende occur in these rocks, though never together so far as the writer's experience goes.

While the one is the ordinary green brown hornblende of the plutonic rocks, the other is a peculiar brown hornblende which seems identical with that recently described by Van Horn in a hornblende-gabbro near Ivrea.[1] It has the same strong pleochroism, a—faint yellow, b—reddish brown and c—orange-brown, with absorption $b \gg c > a$, and the other optical characters are in close agreement. Like that also, it is associated with a green spinel which is only found included in the hornblende.

The distribution of this mineral is peculiar. While it occurs to a slight extent in the granular material mingled with the pyroxenes, garnet and feldspar which compose it, it has in the main an exclusive tendency, occurring in bunches in which the individuals are usually of larger size than the ordinary granular material and have in part good crystal outlines. Sometimes they are clustered around a magnetite crystal or crystals, sometimes no magnetite appears in the cluster. In either case feldspar forms their outer boundary. The phenomena are precisely such as characterize what are known as reaction (or, better, as corrosion) rims. The mineral seems to be of secondary origin in these gabbros and to have been formed as a result of metamorphism from the interaction of feldspar and magnetite, or more rarely augite. A few minute inclusions in the primary feldspars may be, themselves, primary or have resulted from the same process that produced the garnet inclusions. In the Ivrea rock, on the contrary, this mineral is certainly primary, but it does not form corrosion rims and holds the minute inclusions which are found in the other primary minerals and which are lacking in the Adirondack mineral. In the nests in which magnetite is lacking, it is judged to have been there originally and to have been completely used up in the process.

Most of the green hornblende is also secondary, but it makes more show in the granular material than the brown does. The latter is the usual hornblende in the bosses, the green in the dikes. Where the metamorphism has been considerable, only the green appears. Beyond question primary green hornblende occurred in some of these rocks, which must have originally been in part

[1]Van Horn, F. R. Tscher. Min. Petr. Mitt. band 17, heft 5.

hornblende-gabbros, but except for some few small inclusions in the primary feldspars none of this original hornblende remains, recrystallization having been much more complete in them than in the ordinary gabbro.

In addition to the minerals already mentioned, apatite is always present, often abundantly, in these rocks; titanite, pyrite and pyrrhotite occur sporadically, and a little secondary quartz frequently appears, mostly in close association with magnetite. In the granular material a certain amount of the secondary feldspar is usually without striation, and may therefore be orthoclase, but no certainty in regard to this has been reached.

These gabbros as a whole belong to the type to which the name of hyperite has been given by Törnebohm.

These rocks occur numerously in the county in the form of dikes cutting the anorthosites, and such show excellently in the many rock cuts along the New York Central and Hudson River railroad between Saranac and Floodwood. As examples of the bosses may be mentioned; 1) one by the road along the north branch of the Saranac 2 miles east of Hunter's home, which is fairly coarse, of the brown hornblende variety, and has a comparatively unchanged core; 2) another well shown in cuts along the New York and Ottawa railroad between 1½ and 2 miles above St Regis Falls, also of the brown hornblende variety, which shows beautifully the gradual passage of the hyperite into amphibolite gneiss, the extreme phases of which are studded with very large garnets mostly between 1 and 4 inches in diameter; 3) another along the west shore at the head of Lower Saranac lake and running up on Boot Bay mountain, which is quite a large mass and correspondingly coarse; and 4) still another 2 miles northeast of Vermontville, a curious little area inclosed by gneisses which are thought to belong to the augite syenites, in which both hyperite and anorthosite gabbro occur with, as yet, unascertained relations to each other and to the inclosing rocks.

Granite. There seem to be granites of two, possibly of three, different ages in Franklin county. In considerable part they have not been differentiated from one another.

In the northern part of the county, that part mapped as occupied by the doubtful gneisses, there is a good deal of granite. No very large masses have been noted, but there are several small ones which send out tongues into the adjacent gneisses, and from these a series of gradations into exposures showing the gneiss all cut up by small stringers of granite which run in general parallel to the foliation; the phenomena being in short precisely such as are common all over the world where these very old rocks are exposed.

1 mile west of Duane postoffice and a few rods south of the road is a low cliff facing south, showing a rather fine grained, red granite cutting amphibolite gneiss (*see* pl. 7). The granite cuts vertically across the strike of the gneiss for the full hight of the cliff (12 feet), incloses fragments of it and sends offshoots into it. Like most of the granite of the county, it is essentially a quartz feldspar rock, the amounts of magnetite, biotite and hornblende being very insignificant. The feldspar is mainly microperthite, but there is considerable microcline and a little oligoclase. The rock is much metamorphosed.

The gneiss is essentially a plagioclase-hornblende-augite rock. Extinction angles up to 20° indicate an acid labradorite as the feldspar. The augite is not so abundant as the hornblende, but in considerable amount, of green color with slight pleochroism. The rock is not to be distinguished from the gneissoid phases of the hyperite gabbros except for the absence of garnet, usually (not always) abundant in the other rock. The age of the granite is correspondingly uncertain, though of course it is younger than the gneiss which it cuts. Just across the creek, 200 rods to the southwest, the same rock association appears.

For a wide area around St Regis Falls and Dickinson Center the prevailing rock is an amphibolite gneiss identical with that just described. Sometimes all pyroxene is lacking, sometimes hypersthene is present in place of augite. These gneisses are all cut up by granite which appears in small bosses or else in thin bands in the excessively contorted gneisses. The granite varies much in grain, being at times quite coarse, as at St Regis Falls

in the river bed (*see* pl. 8). There are also bands of reddish orthoclase gneiss along with the dark amphibolite gneiss, which are thought to be a part of the series and to have nothing to do with the granite, though decisive evidence on this point is lacking.

Though no large masses of this granite have been discovered, the total amount present is considerable. While clearly intrusive in the gneiss and hence younger, it is thought to be much older than the anorthosite, implying also that the amphibolite-gneiss is older than the gabbro. The reasons for holding this view are briefly as follows:

1 The amphibolite gneiss is very widespread in Dickinson and Waverly townships, and does not show massive cores, such as are nearly always found in the hyperites, which are known to occur only in small masses or in dikes. Two such small masses occur in the immediate vicinity, one to the south of the falls along the railway and the other near the road less than 2 miles west of the village, both with unchanged cores and gneissoid periphery. While no contacts show, these outer gneisses differ somewhat in appearance from the main body of gneiss and are not at all involved with granite. The presence of granite, the more widespread character of the deposit and the more complete metamorphism are the reasons for assuming the older age of the amphibolite rather than regarding it as identical with the gabbro.

2 The granite occurs so abundantly and constantly cutting these rocks that it seems incomprehensible that it should not be found cutting the syenites and anorthosites to the south if it is really younger than they. This association of this red granite with amphibolite and also with orthoclase gneisses is constant in the northern Adirondacks and must have some significance.

There are however later granites also. Those associated with the syenites and distinguished by their coarse grain and spindle-shaped quartz have been already described. In addition small masses of granite have been found in a few places in the anorthosite, but unfortunately their precise nature is not clear. They resemble the older granite, and some of them are unmistakable in-

Plate 7

Irruptive contact of granite against amphibolite gneiss, 1 mile west of Duane postoffice. Granite at left, gneiss in center and to right, cut at the base by the granite, the contact showing best just above the hammer

clusions of small size caught up by the anorthosite from the inclosing rocks. Others may either be dikes or somewhat larger inclusions. In two cases the resemblance to dikes is strong, but the exposures are not sufficiently extensive to furnish a demonstration, so that the matter must be left open for the present.

In addition to the above granites there are sometimes found, cutting the anorthosites, curious dikes of a fairly acid rock with porphyritic feldspars and finely granular ground mass which resembles somewhat some of the later syenite porphyry. The ground mass is evenly granular and appears to have been completely recrystallized. These dikes have not been thoroughly studied as yet, and are at present regarded somewhat doubtfully as syenite dikes, whose slight width is accountable for their porphyritic character.

Diabase. Much later than all the foregoing are rocks which make comparatively small showing in Franklin county. While of several subordinate types, they may all be conveniently classed as diabases, the distinction between them and the hyperites not being a sharp one. They are said to be much later, since they are not in the least metamorphosed, and have apparently solidified at much less depth than any of the other eruptives; hence a long intervening period of erosion is argued.

These are black, very fine grained, flinty rocks with conchoidal fracture and are very easy of recognition. They occur only in dikes which range from a few inches up to 30 or 40 feet in width, more commonly being from 1 to 10 feet, are nearly vertical, and have an east and west trend, small offshoots only excepted. Near the wall rocks cooling has been so rapid as to forbid much crystallization, and the rock is glassy. The considerable variation in grain from the sides to the center of these dikes, showing in all but the exceedingly narrow ones, is one of their most distinctive characters, and is in marked contrast to the even grain of the hyperite dikes. They weather out into small, sharp-edged blocks along planes produced by contraction on cooling. They are not likely to be confused with any of the other rocks except possibly some of the hyperite dikes, but these last, in addition to their

evenness of grain, do not weather into blocks, are often schistose and usually show the red tinge due to the presence of garnet, which seldom appears in the diabase.

An interesting feature of these dikes, which has been emphasized in previous reports, concerns their distribution. In Clinton and Essex counties they are very numerous, so much so as to form in places quite a respectable proportion of the whole rock mass. In Franklin and Hamilton they are much less abundant, and in Franklin at least they are mostly in its eastern half. In the western Adirondacks they are practically absent.

They are also more abundant in the north than in the southeast, more being found to the unit of area in Clinton than in Essex. In other words, they are most concentrated toward the northeast, so that the main center of the igneous activity must have been in that region. Close to the Potsdam boundary in Clinton they make a very impressive display. They may be even more abundant beneath the cover of the later rocks to the northward.

Along with the diabases, though much fewer in number, are complementary acid dikes which may be classed as a whole as syenite porphyries. These show the same center of activity though not spreading so far away from it. They are practically confined to Clinton county and are most abundant near the Potsdam boundary. They range from red to brownish black in color, average wider than the diabase dikes and are more apt to contain large, porphyritic crystals.

In Franklin county 37 dikes have been noted to date, though these can be but a small proportion of the whole number. Their situation is indicated on the accompanying map. Two are of syenite porphyry, the only two dikes of this rock so far met with in the whole Adirondack region outside of Clinton county. The others are all diabases. Several of these hold bronzite, not a common mineral in the Adirondack diabases which have hitherto been described. There are several types present, as already stated, and they merit a more detailed description than they have yet received.

Plate 8

Falls of St Regis river over well-jointed granite; St Regis Falls village

As nearly all the dikes have prophyritic feldspar, or augite or both, they are strictly diabase porphyrites, and this is to be understood in the table which immediately follows. In the large dikes the porphyritic structure fades out in the center, with increasing size of the ground mass constituents, the structure becoming either ophitic or gabbroic. All the dikes show intersertal, or even vitrophyric structure near the borders, according to the amount of glass present.

Where the dikes have porphyritic structure, olivine is of the first generation only, and is so to be understood in all olivine diabase in the table.

Tabulation of Franklin county dikes

NO.	TOWNSHIP	LOCALITY	WIDTH	STRIKE	WALLS	NAME	REMARKS
1	Malone	By road 200 rods from Belmont line	1 ft	s 70° e.	Gneiss	Olivine diabase	Porphyritic feldspar and augite
2	Belmont	Near schoolhouse 6, south of road	4 ft	n 80° e.	"	Bronzite olivine diabase	Porphyritic bronzite and augite. Spherulitic arrangement of ground mass feldspar and augite
3	Burke	Mackenzie's mill	27 ft +	n 65° e.	Granite	Syenite porphyry	
12	"	14 yd. north of no. 3	15 ft	n 65° e.	"	Diabase (?)	Abnormal. Belongs likely with the syenite porphyries
10	"	20 rods west of river at Mackenzie's	2 ft +	n 65° e.	"	"	Porphyritic feldspar only. Many gneiss inclusions
11	"	20 yds south of no. 10	6 ft	e & w.	"	"	Porphyritic feldspar only
4	Malone	¾ mile south of Whippleville by road	3 ft	e & w.	Gneiss	"	Porphyritic feldspar with also sparse augite
5	"	Edge of Cornish hill near road	12 ft	n 75° e.	"	Syenite porphyry	
6	"	Edge of Cornish hill near four corners	20 ft	s 80° e.	"	Olivine diabase	Porphyritic augite and feldspar
7	Brandon	By road just south of creek	26 in	n 80° e.	"	"	Porphyritic feldspar and augite
8	Belmont	Just north of schoolhouse 12	16 in	s 65° e.	"	"	"
9	"	80 rods south of last on Kirby's place	20 ft +	(?)	"	"	Not porphyritic in center
13	"	On ridge at edge of marsh south of Upper Chateaugay lake	2 ft	e & w.	"	"	Porphyritic augite, not feldspar
14	"	By brook ¾ mile west of Standish	28 ft	s 75° e.	"	Diabase	In seven branches. Amygdaloidal. Porphyritic feldspar and augite

Tabulation of Franklin county dikes—*continued*

NO.	TOWNSHIP	LOCALITY	WIDTH	STRIKE	WALLS	NAME	REMARKS
15	Belmont	150 yards south of old ore pits, Chateaugay railroad	1 ft	(?)	Gneiss	Bronzite diabase	Beautiful parallel growths of bronzite and augite
16	"	50 yards north of same ore pits	30 in	(?)	"	Diabase	Much decomposed
17	Franklin	West face of Catamount mt, Loon lake	1 ft	n 70° e.	Augite syenite	Olivine diabase	Porphyritic feldspar only
18	"	½ mile southwest of last on same hill	2 ft	n 70° e.	"	Diabase	Very feldspathic; porphyritic feldspar only
19	"	First rock cut south of depot, N. Y. C. & H. railroad	3 ft	n 65° e.	"	"	Not porphyritic
20	"	Just across river from Goldsmith's	15 in	n 80° e.	Gneiss	Olivine diabase	Badly decomposed
21	"	By roadside just east of Franklin Falls postoffice	4 ft+	e & w	Anorthosite	Diabase	Not porphyritic
22	"	By road ¼ mile north of Franklin Falls	12 ft	e & w	Gabbro (?)	Olivine diabase	Very fresh. Holds inclusions of finer grained diabase
23	"	East of road, 20 rods south of old limekiln	2 ft	n 75° e.	Grenville series	Diabase	Amygdaloidal; porphyritic feldspar only
33	"	Near three corners in road south of 23	9 ft +	e & w	"	Olivine diabase	Large porphyritic feldspars
34	"	On cliffs, north side of river, 80 rods east of Franklin Falls bridge	5 ft	n 75° e.	"	"	Porphyritic feldspar only; possibly extension of 22
24	Duane	By road one mile north of McCollum's	(?)	(?)	Gneiss	"	Porphyritic augite and feldspar
25	Brighton	By road on side of Mt Pond mountain	2 ft +	(?)	Anorthosite	"	Divergent-rayed structure in ground mass
26	Duane	Top of Debar mountain	3 in	n 70° e.	Brown gneiss	No specimen	
27	"	One mile west of Woodford, south of road	6 in	s 85° e.	Hornblende gneiss	Diabase	Variolitic; porphyritic bronzite (?) and olivine (?), both completely decomposed

Tabulation of Franklin county dikes—*concluded*

NO.	TOWNSHIP	LOCALITY	WIDTH	STRIKE	WALLS	NAME	REMARKS
28	Duane	By road just west of Deer river	6 ft	n 80° e.	Gneiss	Bronzite diabase.	Beautiful divergent-rayed structure
29	Malone	North of road near Chasmfalls bridge	30 in	s 75° e.	Augite syenite	Olivine diabase	Porphyritic augite only
30	"	$\frac{1}{8}$ miles 30° e from V. Fayette's	7 ft	n 75° e.	Brown gneiss	"	Non-porphyritic
31	"	100 yds east of bridge over Branch pond outlet	20 ft	(?)	Gneiss	Diabase	No slide
32	Waverly	South of road $3\frac{1}{2}$ miles east of St Regis Falls	14 in	e & w	Granite	Olivine diabase	Large porphyritic feldspars
35	Harrietstown	On mountain side, $\frac{1}{8}$ mile southeast of Ampersand pond	1 ft	n 75° e.	Anorthosite	"	
36	Santa Clara	Railroad cut, $1\frac{3}{4}$ miles south of Brandon	14 in	n 50° e.	"	"	
37	Harrietstown	Railroad cut, 4 miles from Saranac	66 in	n 60° e.	"	Diabase	Porphyritic feldspar only; amygdaloidal

Eruptive rocks of Silurian age. Igneous activity did not cease in the Adirondack region with the close of the period of diabase extrusion, but with a much later period of dike formation. The eruptive center of this period seems to have been in New England, and the dikes found in New York are practically limited to the immediate shores of Lake Champlain. Kemp has described several from Essex county, and the writer a few from Clinton. Both acid and basic rocks occur, but in each case they differ somewhat from the Precambrian eruptives in type, so that there should be no difficulty, usually, in making determinations of age. No dikes which can be ascribed to this period have been found in Franklin county, and the strong probability is that they do not occur.

PALEOZOIC ROCKS

Much later than all the previously described rocks of Franklin county are the Potsdam sandstone, of Upper Cambrian age, and the Calciferous dolomites and limestones, of Lower Silurian age, which are found in the northern part of the county only. The overlying Chazy and Trenton limestones do not appear in the county so far as known. These rocks have been briefly discussed in a previous report, and no additional work has been done on them.[1]

These rocks were laid down on a much eroded floor of the older rocks. Apparently the Adirondack region was a land area for a larger part, if not the whole, of the long time interval between the deposition of the Grenville series and of the Potsdam sandstone. During this interval the amount of material eroded away from the region was very great, apparently greater than the entire amount removed since Silurian times, since which it has also been continuously above sea level.

A single observation made far within the area occupied by the Precambrian rocks, in 1897, is of considerable interest. An old limekiln stands near the road running north from Alderbrook postoffice to the north branch of the Saranac, somewhat over 2 miles from the former. Before visiting the place it was inferred

[1] Cushing, H. P. 16th an. rep't N. Y. state geologist. 1896. (geol. map) p. 5–27.

that crystalline limestone of the Grenville series would be found near at hand. However, no rock outcrops of any sort could be found in the immediate vicinity, though occasional loose blocks of Calciferous limestone were noticed lying about. Inquiry in the neighborhood elicited the information that it was such that had been burned in the kiln, that they were formerly there in great abundance, and that no rock ledge had ever been worked to supply the kiln.

Now except just here locally, Calciferous boulders are very infrequent in the vicinity. The nearest outcrops of any paleozoic rock are of the Hardscrabble Potsdam in Clinton county, nearly 15 miles away. The nearest Calciferous ledges are over 20 miles distant in the same direction, that is to the northeast. The writer can account for the occurrence at the kiln only by supposing the former existence there of a small outlier of Calciferous rocks, of which the loose blocks represented the final trace. Many of the limestones of the region weather out into a multitude of loose blocks by more rapid solution of the rock along the joint planes and by the subsequent disrupting action of frost, which raises and tilts the blocks so that they lie loosely about, slanting in all directions. This effect is shown beautifully in many places in Clinton county where limestones are exposed, and where the blocks are assuredly nearly in place, and yet wholly conceal the ledges underneath.

If this be the true explanation, here the occurrence recalls the Calciferous outlier at Schroon lake, Essex county, described first by C. E. Hall and more recently by Kemp, as well as similar and larger areas in the southern Adirondack region.[1] The limestone may have been deposited directly on the Precambrian floor, that is, it is beyond the limits of Potsdam deposition. If this be true, important conclusions will follow as to the conditions of the dry land area which would permit a limestone being deposited directly on the old surface. But, as the occurrence is somewhat problematic and may represent simply a small block along a fault plane,

[1]Hall, C. E. 32d ann. rep't N. Y. state mus. nat. hist. 1879. p.39.
Kemp, J. F. Bul. geol. soc. Amer. 1897. 8:411.

it will not do to lay much emphasis on its possible bearing on the question of the topographic character of the surface on which the paleozoic rocks were deposited.

ECONOMIC GEOLOGY

The mineral deposits of the county which have been, are now, or are ever likely to be of any economic value are the magnetic iron ores, the Potsdam sandstone and perhaps some of the Precambrian rocks also as a source of building stone, the latter rocks for road metal, and the limestones as a source of lime. There is a possibility that brick clays may occur, though none have been noted. From the standpoint of the present all these may be dismissed in a few words.

Iron ore. There are a great number of old ore pits in Franklin county, specially in Belmont, Duane and Franklin townships. Emmons mentions ore worked near Saranac, in Santa Clara (township no. 11), several localities around Duane Center, and an opening 4 miles west of Malone (probably on Cornish hill).[1] That represented the condition of the industry up to 1840, but in the succeeding quarter of a century many more openings were made. Emmons also notes that the ore is in different association from most of the Essex and Clinton county ore, occurring in black amphibolite gneiss rather in the red, orthoclase gneiss full of titanite, which is the usual rock in those counties. Emmons's generalization also holds good for the deposits opened since his report was published.

None of these deposits were of very large size, none of them have been worked this many a year, and there is no prospect that any of them can be worked with profit in the immediate future. It is only the unusually large and rich deposits, such as those at Mineville and Lyon mountain, that can be worked with profit under present conditions of the iron industry; and it is only the recent rise in prices which has permitted work to be resumed at Lyon mountain, the mines having been shut down for several years previous to 1898.

[1] Emmons, Ebenezer. Geology of New York. pt 2, p. 326–31.

Large deposits of titaniferous magnetites in the anorthosites, similar to those which supplied the ore for the old iron works at Lake Sanford, in Essex county, are unknown in Franklin, though such may occur. Iron ore is known to exist on the unnamed mountain situated in the hilly tract to the north of Big Wolf pond in Altamont township, but the locality is rather inaccessible, and has not been visited by the writer, nor is the extent of the deposit known.

It is by no means impossible that similar deposits may be discovered in township 27, on or about Mt Seward. This is one of the wildest, most inaccessible, and least known tracts in the whole Adirondack region, and has never been exploited for iron so far as the writer is aware. But, even if extensive deposits exist, they would have but a prospective value, owing to the prejudice against, and non-use of titaniferous ores in this country at the present day.

Building stone. The only building stone quarries known to the writer in Franklin county are all in the Potsdam sandstone and mostly confined to the vicinity of Malone. These are all in the upper part of the formation, and quarry a white or buff stone of fair to good quality which has mostly only a local use. The lower, red beds, such as are quarried at Potsdam, make but small show in outcrop in the county. At many places farmers have made small openings in this formation for stone for their own use. There must be an inexhaustible supply of good stone in this formation, but outcrops are very infrequent considering the extent of surface occupied by the rock, and no stone of the quality and character of that quarried at Potsdam has been noted.

None of the Precambrian rocks of the county have been used for building purposes, though some quarrying has been done in anorthosite-gabbro at Keeseville and, more recently, on Rand hill in Clinton. Nor is there likely to be any use of these rocks for such purpose for a long time, except possibly an exceedingly restricted local use. Yet there is a vast amount of good stone for building and monumental purposes, the syenites, granites and anorthosites all being capable of furnishing good material. All present phases which are very durable and take a fine polish.

Road metal. The roads in the county are mostly poor, many very poor. In the northern portion the east and west roads are on glacial deposits and are fair, but the north and south roads are largely in the vicinity of the streams, with their extensive sand deposits, and are excessively sandy and poor. Back in the hills the roads are usually not much traveled and are naturally not well kept. But in places good roads have been constructed. Just around Paul Smiths, specially on the road to the depot and thence part way to Bloomingdale, recent great improvement has been made by covering the surface with a layer of stone broken by a rock-crusher, then covering with fine material and rolling with a heavy steam roller. The rock used was obtained from the abundant, loose boulders of crystalline rocks in the vicinity, some of which serve excellently well and some not so well. But the whole makes a very good road and one that should stand for a long time with the present moderate amount of travel, specially if kept in good repair. The road from Tupper lake to Litchfield park and those in the park itself are excellently made and though not macadamized are carefully graded and covered with gravel.

These roads furnish good object lessons to the community, and the most excellent rock materials for road construction occur all over the county, so that it would nowhere be a matter of great expense to obtain such. The larger diabase dikes, the gabbros and much of the anorthosite and syenite furnish perhaps the best material among the Precambrian rocks, either for a single course of broken stone or for the upper layer of a Telford road. The more durable layers of the less quartzose gneisses would also serve fairly well.

Some of the purer and firmer portions of the Calciferous formation would also furnish capital road material either singly or for the lower course of a Telford road.

The Potsdam sandstone, which is used as a road material around Potsdam, is wholly unfit for such purpose, as is almost any sandstone, since it breaks down more or less rapidly to a pure quartz sand, with the result that the last stage of the road is worse than the first.

Lime. The writer does not know that any lime is burned in Franklin county at the present day. In the old days the crystalline limestone of the Grenville series was burned for lime, and some of the old kilns are still standing. The old kiln near Alderbrook in which the Calciferous was burned has already been mentioned. With the possible exception of some layers of the Calciferous, these produce lime of very inferior quality compared with that obtained from the Black river and Chazy limestones along Lake Champlain, which are quite near at hand. The former use of the crystalline limestone as a flux has of course lapsed with the dying out of the iron industry.

REPORT ON PROGRESS MADE, DURING 1898, IN MAPPING THE CRYSTALLINE ROCKS OF THE WESTERN ADIRONDACK REGION

Part 4

C. H. Smyth jr Ph.D. and D. H. Newland M.A.

CRYSTALLINE ROCKS OF THE WESTERN ADIRONDACK REGION

The field work for 1898 in the western Adirondacks was planned with reference to the desire of the late Dr James Hall, state geologist, to issue during the present winter a new edition of the geologic map of the state.

With this end in view, every effort was made to cover all of the ground remaining unexamined, while the detailed study necessary for a clear understanding and accurate delimitation of the formations was almost wholly neglected.

The region studied embraces large areas in the central and northern parts of western Hamilton county, the northern third of Herkimer county, and the southeastern corner of St Lawrence county. These areas are practically all covered with dense forest, the topography is rugged, and lines of travel few and difficult. These, and other conditions, combine to make field work arduous, and results unsatisfactory. A partial compensation is afforded by the comparative uniformity of the rocks over wide areas.

After covering this part of the region, a hitherto unstudied area in northwestern St Lawrence and northeastern Jefferson counties was taken up. This area adjoins the region in which most of the work of previous years has been done, and shows the same complex geology. Yet in spite of this complexity, the writer is convinced that this part of the crystalline area is by far the most favorable for the solution of the problems afforded by the gneisses, granites, syenites and crystalline limestones. But, as already stated, no time was afforded for the study of these problems during the past season. The areal work was done under the writer's direction by D. H. Newland, and, as no changes of classification or nomenclature have been introduced, such formational terms as are used in the present report are to be understood in the same sense as in the two preceding reports. In the latter, it has been pointed out how far from satisfactory and final these terms

are, but it has also, doubtless, been made equally clear that a more definite meaning can be attached to them only as the result of long and careful work.

As yet, not one of these formations has been accurately delimited over any wide area, in part on account of the perplexing intermediate varieties which are so frequent, in part on account of the absence of good base maps, but even more because the work has necessarily been done very rapidly.

Under the most favorable conditions, the accurate mapping of the region must be attended with much difficulty; and the results as yet obtained must be regarded as far from final.

This is particularly true of the gneisses, which are very complex and troublesome. Some gneisses are igneous and some sedimentary in origin, without question, and it is probable that the former class includes most of the gneisses of the region; but, at present, it does not seem advisable to attempt any separation of the gneisses, except to include in the limestone formation such as appear certainly to be a constituent part of it. The gneiss, therefore, as represented on the map, must be regarded as by no means a unit, though it is probable that a large proportion of it constitutes a single formation, or at least is made up of rocks so closely related in origin and age that they can not be separated. But it surely comprises portions of the limestone formation, as well as more or less modified later intrusive rocks, impossible to separate except by close work.

The limestone formation is indicated only where the actual limestone is present or some of the characteristic associated schists appear, and therefore there can be no question that many small areas of the formation are not represented.

The same may be said of gabbro, various basic gneisses which may possibly be modified phases of this rock being included with the gneiss.

Granite and syenite are indicated only when the proximity of limestone makes easy the determination of their intrusive nature.

Between the granites and syenites, on the one hand, and the gneisses on the other, it is impossible to draw any sharp distinc-

tion, as they are connected by every intermediate stage, and it is clear that the former are massive phases of a part, at least, of the gneissic complex. As, however, the age and origin of large areas of the gneiss are as yet inferential, it seems advisable to indicate the granites and syenites wherever possible, keeping constantly in mind their close connection with the gneisses.

No attempt has been made to trace in detail the boundary between the crystalline and paleozoic rocks, and only incidental data bearing on this point have been accumulated.

The work of the season has almost completed the reconnaissance of the western half of the Adirondack region. The extreme southern part of Hamilton county and the adjacent part of Herkimer county have not yet been examined, and the same is true of the vicinity of Black lake in St Lawrence county, and some other limited areas in the northern part of the region. As to the first gap, that in Hamilton and Herkimer counties, it is practically certain that it is an area of gneiss with small limestone patches. But in the north there is so much variation in the rocks that decided changes may come in suddenly and unexpectedly. To the southwest of Black lake, directly in the line of strike, limestone, gneisses and granites occur in profusion, and, as limestone is known to occur on the shore of the lake, there can be no doubt that, in a general way, this small area agrees with the region examined about Rossie and Redwood, but as to details nothing is yet known.

From what has been said above, it is evident that the results of the season's work are chiefly areal. Nevertheless, in four particulars some light is shed on genetic and structural problems.

In the last report it was shown that the hypothetic gabbro core of the Adirondacks, with its narrow fringe of gneisses having quaquaversal dip, has no existence, but, instead, that the region consists chiefly of gneisses, cut by immense gabbro intrusions on the east. Still, as there stated, it had not been shown that there might not be areas of gabbro of some magnitude in the western part of the region. This point is now settled; and it is clear that in the entire western half of the Adirondack region gabbro occurs

only in scattered areas of small extent, wholly inadequate to exercise any influence on the general metamorphism of the region.

A second result of interest is the finding of frequent lumps and lenses of hornblende gneiss scattered through the more acid gneisses all over the region. These masses are analogous to the fragments described in the report for 1895 as probable inclusions in an igneous gneiss. That they really are such now seems quite certain, and they are regarded as affording most important evidence as to the origin of the gneisses.

A third phenomenon appears in the region about Longlake station, where a light red granitoid gneiss seems, without doubt, to be intrusive in an older gray gneiss. This is directly in line with facts observed near Gouverneur, St Lawrence county, also described in the report for 1895, and, as there stated, shows that all parts of the gneiss are not of the same age.

Finally, the red granitoid gneiss in the vicinity of Alexandria Bay, on the St Lawrence river, was found to be younger than and intrusive in the adjacent schists, which doubtless belong to the limestone formation. This is analogous to many instances previously described in St Lawrence and Lewis counties, but is, if anything, more clearly defined. It is important in affording another example of an undoubted igneous gneiss, which in every way closely resembles the great areas of gneiss farther south, that are regarded as igneous, and yet, on account of the absence of other formations, show no conclusive proof of their origin. Furthermore, this Alexandria gneiss contains many hornblende inclusions almost identical with the widespread hornblende masses in the gneiss formation mentioned above. Final conclusions as to the origin of these gneisses must be based chiefly on analogy and internal evidence, such as composition and texture, and every new occurrence of closely related rocks whose origin is clear is a step toward the solution of the problem.

This occurrence of intrusive gneiss at Alexandria Bay is also important in its bearing on the question of time relations. It has been generally assumed that either the gneiss and limestone are one formation or that the gneiss is the older, the latter view

being the more prevalent. But in the report for 1895 it was shown that several large areas of gneiss are younger than the limestone; and both in that and in the report for 1897 it was stated that there is nothing to show that the limestone is not the oldest formation of the region. Like the question of origin, that of relative age must always be troublesome and, in many cases, be answered only by indirect evidence; hence, again, the importance of localities, like the one under consideration, where the relation is evident.

As already intimated, the general areal relations indicated in the report for 1897 have been found to hold good for the entire western half of the Adirondack region, gneisses being the predominant rock, with minor crystalline limestones, granites, gabbros, etc.

In regard to the gneisses, one farther point demands particular mention. In the last report much space was given to the discussion of the augite syenite of Diana and Pitcairn, and it was shown to pass over into typical gneisses. Much evidence indicates that the syenite gneiss is a widespread and important rock; and Prof. Cushing has described[1] large areas in Franklin county. In the field work of the past season it was found impossible to separate this rock from other gneisses in the time available, and, as previously said, it therefore is not distinguished on the map except in the single type locality where its relations to the limestone show its undoubted intrusive nature.

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[1] Bul. geol. soc. Amer. 10:177-92.

PRELIMINARY REPORT ON THE GEOLOGY OF HAMILTON, WARREN AND WASHINGTON COUNTIES

Part 5

By J. F. Kemp B.A. M.E., D. H. Newland B.A. and B. F. Hill M.A.

CONTENTS

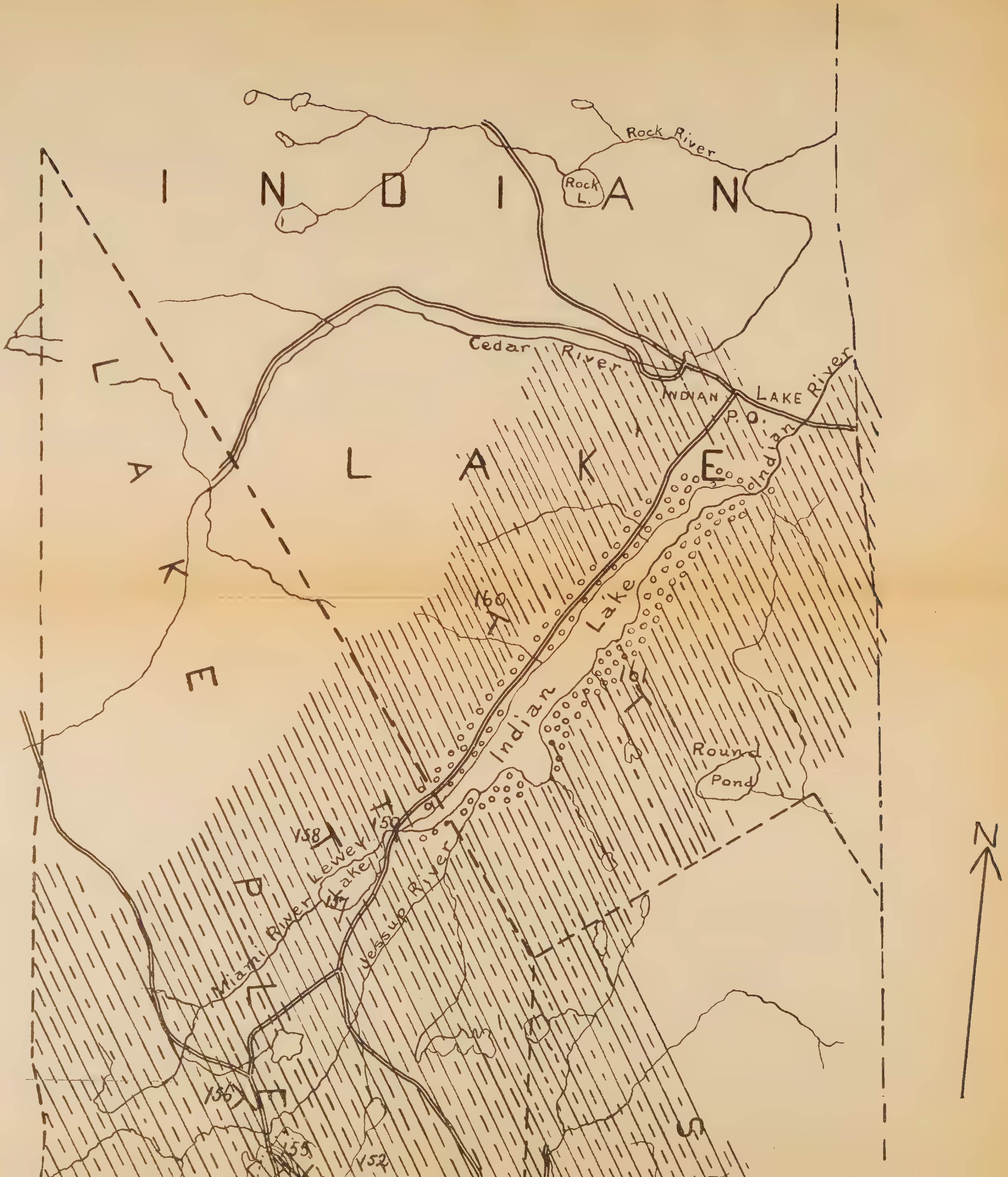
Dr John M. Clarke

Sir: I submit herewith a report on the fieldwork performed during the season of 1898 in the southern Adirondack region, under my direction. The principal area lies in Hamilton and Warren counties near the border of the two, but some additional observations were made in Washington county. The fieldwork was chiefly done by David H. Newland B.A. and Benjamin F. Hill M.A. The report and maps have been prepared by myself on the basis of their notes, and in a part of the area I have made some observations myself.

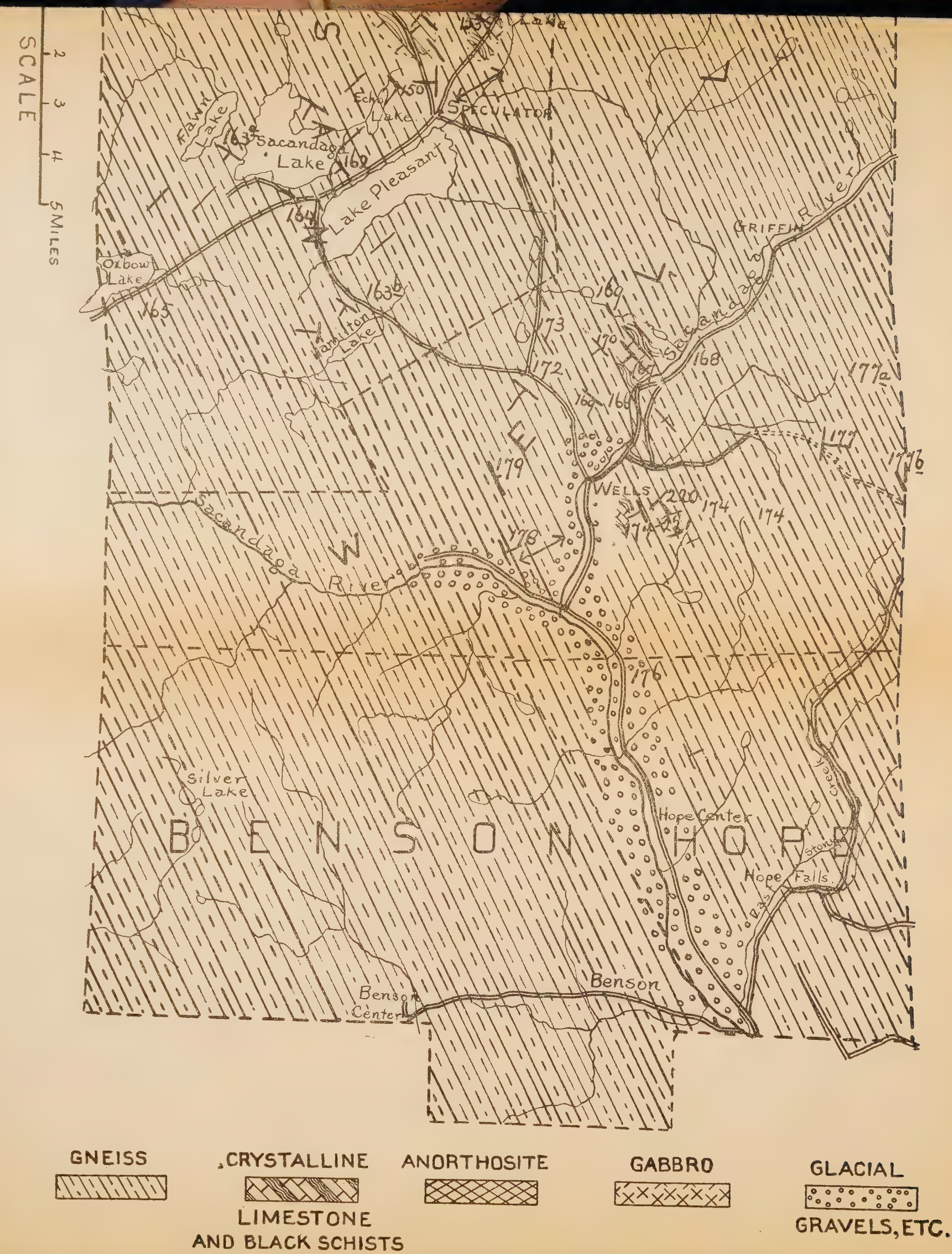
Very respectfully

J. F. Kemp

Plate 1



INDIAN
LAKE
Rock River
Rock L.
Cedar River
INDIAN LAKE P.O.
Indian River
Indian Lake
Lake
Round Pond
Miami River
Lewey Lake
Jessup River
160
158
150
156
155
152
N



GEOLOGIC MAP OF BENSON, HOPE, WELLS, LAKE PLEASANT AND INDIAN LAKE TOWNSHIPS, HAMILTON CO.

INTRODUCTION—OUTLINE OF GENERAL RESULTS

The fieldwork for the accompanying report was performed in the summer of 1898. The observations on Johnsburg are the work of Mr Newland; those on the townships in Hamilton county were chiefly gathered by Mr Newland, who was assisted for a time by Mr Hill; the data in Fort Ann, Washington co., were collected chiefly by Mr Hill. Prof. Kemp has been over some of the areas independently and has prepared the report and maps. The present report extends to the westward and southward the observations of the previous season.[1] The points of special interest are the outlying areas of anorthosite in Johnsburg; the outlier of paleozoic strata in Wells, which is here quite fully discussed; and the increasing certainty of the existence of sedimentary gneisses in Fort Ann and Johnsburg townships.

A general discussion of the provisional scheme of classification adopted will be found in our previous report, just cited.

LOCAL GEOLOGY BY COUNTIES AND TOWNS

Hamilton county

Benson

Topography and geology. Benson is a mountainous and very sparsely settled township in the southern part of the county and lying just west of Hope. The two villages of Benson and Benson Center are situated near the southern line, but north of these there are almost no roads, and the country is quite inaccessible. It forms the hight of land between the headwaters of West Stony creek on the south and the west branch of the Sacandaga river on the west, north and east. The latter rises in Silver lake, flows south, then west, then north beyond the limits of our map, then east through Wells township, and finally south through Hope. Our explorations have been limited to the southern part of the

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[1] Kemp, J. F. & Newland, D. H. 17th an. rep't N. Y. state geologist. 1897. p. 499–553.

town, but from the general relations we think that gneisses make up practically its entire area, unless there are some small limestone outcrops or gabbros of which we have not learned. In the drift a number of anorthosite boulders were observed, but none of the rock in place. The prevailing gneiss is fairly massive, and is often red from the large amount of red feldspar. The strike is n 10 e magnetic, n 22 e true meridian, as observed near the two Benson villages. Along the highway connecting these two the gneiss is a crushed and sheared augite syenite and is very thinly laminated. It is dark green in color when fresh, but weathers to a rusty brown. The glacial drift is widespread in the valleys.

Hope

Topography. Hope is a small and sparsely settled township in the southeastern corner of the county. Its surface is hilly, and, while there are no elevations of very great altitude, ridges almost entirely make it up. There are two prominent valleys, which are occupied respectively by the waters of the Sacandaga river on the west, with a southwesterly course, and East Stony creek on the east, with a southeasterly course. Even these valleys are narrow, being shut in by steep hills, and afford but a slight foothold for agriculture. Highways of considerable importance traverse them, the one along the Sacandaga being specially used by summer visitors passing from Northville to Piseco lake, Lake Pleasant and other resorts. Lakes are notably deficient; only one small one is found, and that is in the northern central part of the town.

Series 1. While the remoter and less accessible parts of the town have received but slight attention, yet all the outcrops of rock studied belonged to this series, and it is doubtful if any except the glacial drift is met. If present, the other series would be of small extent. The prevailing gneiss contains orthoclase or microperthite as its chief feldspar, and hornblende as the prevailing dark silicate. Specimen 176 from the Sacandaga valley, near the northern boundary of the town, exhibits in thin section, orthoclase, microperthite, very little quartz, and a moderate

amount of green hornblende. This is syenitic in its nature, and is like the Loon lake rocks of Franklin county and the rocks of southern Benson. No. 176 is, however, greatly crushed and granulated. Along the Sacandaga valley in the southern part of the town an augen-gneiss with biotite is quite extensively developed.

The general strike of the gneiss is n 35 w when referred to the true north, and the dip is about 45 n e.

Series 6. In the valley of the Sacandaga the drift is largely water-sorted and lies in terraces up to 40 or 50 feet above the stream. Unsorted drift is also abundant throughout the town, and its boulders embrace gneiss, gabbro and anorthosite.

Wells

Topography. Wells is a large, irregularly boot-shaped township, 20 miles long from north to south, and 15 miles wide on the south. The width on the north in the leg of the boot, is about 6 miles. The east branch of the Sacandaga runs southwest across the southeastern corner, while the west branch flows easterly across the southern part. The surface of the township is formed by a succession of extremely rugged hills, which are closely set together. The average altitude is moderate but it gradually increases to the north. Both the east and west branches of the Sacandaga are swift streams, till they unite, and then the descent is more gradual and the current less swift. A number of ponds occur throughout the town, but none are specially large. The valleys are as a rule narrow and are inclosed between steep walls. Except the west branch of the Sacandaga, practically all the streams flow southwest, following the general trend of the valleys.

Geology. Special interest attaches to the geology of Wells on account of the outlier of Cambrian and Lower Silurian strata that is found near the village of Wells, and which will be fully discussed later. In addition, the other five series of formations, under which the rocks have been customarily grouped in our descriptions, are present, except no. 5, which embraces the trap dikes. The latter may be present, as our explorations have been

incomplete in some parts of the town, though general experience so far as hitherto gained, has indicated a decrease, if not a failure, of dikes in the southern central and southwestern crystalline areas.

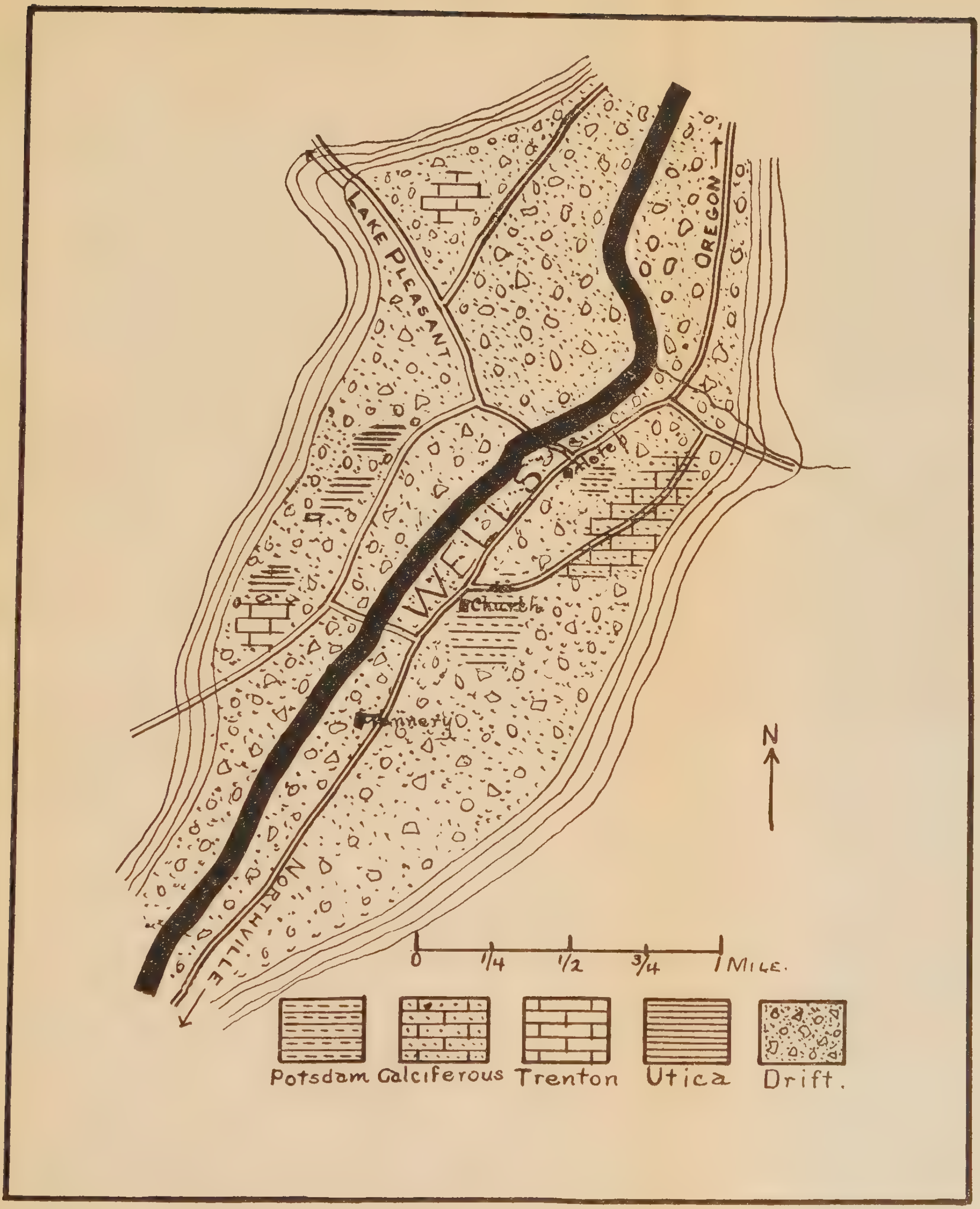
Series 1. Gneisses. The rocks of this series are much the most important of all and constitute almost the entire area. Several different varieties of gneisses are recognizable. The most widespread is one typified by specimen 179, from the hills to the west of Wells village. It is a rock that is greenish when fresh but red when weathered. The chief minerals are biotite, orthoclase, quartz and plagioclase. Garnet is abundant, and pegmatite streaks run through the outcrops. This particular rock bears witness to fairly severe dynamic metamorphism, but others have suffered much more and still others less. No. 170 is a granite not very badly crushed, while 169 and 172 are of the same general composition but are rolled out into thin layers. No. 174 almost if not quite approximates a schist, and under the microscope displays biotite, quartz, plagioclase, orthoclase and garnet, granitic gneiss, and must lie along some old fault line or line of crushing. No. 176 is a syenitic gneiss, and under the microscope exhibits orthoclase, microperthite, strained plagioclase and hornblende. No. 220 just on the ridge northeast of Wells village is the same.

In the hornblendic gneisses are bands of nearly pure hornblende, which may contain pyrite. These bands may be several feet thick. One of exceptional persistence is exposed at locality 178. They are always parallel to the foliation both in dip and strike, and, if they are sheared trap dikes, the foliation has been induced in a direction parallel to the original strike of the dike.

The strike of the gneisses is prevailingly northwest and southeast, but it shifts occasionally even to a bearing at right angles with this. Changes in the direction of the dip are also often observed.

The gneisses are extensively jointed, and often exhibit emphatic escarpments along the line of the major joints; still it is not easy to discriminate these steep cliffs from fault scarps. Just to the northeast of Wells village the joints run n 80 e and n 15 e true bearing, and the former gives rise to cliffs and ledges.

Plate 2



GEOLOGIC MAP OF THE VICINITY OF WELLS VILLAGE, HAMILTON CO.

Series 2. The crystalline limestones and their associates are represented in two areas, respectively northeast and east of the village of Wells. The former yielded specimen 167, and is an extremely impure variety. The rock is so charged with pyroxene, quartz, feldspar and graphite as to have but a comparatively small amount of calcite. No. 222, from the latter locality, is very richly speckled with pyroxene, but some streaks of fairly pure, coarsely crystalline marble were recorded. Pegmatite, however, and quartz were associated with it. Both these small outcrops were inclosed in gneisses and ran parallel to the foliation.

Series 3. A single gabbro intrusion has been observed at 221, due east of Wells village. The gabbro is of the usual basic type found in the Adirondacks, and is faintly foliated from pressure. Boulders in the drift suggested the possibility of the presence of anorthosite in the northeastern part of the town, over toward the known areas of this rock in Johnsburg, west of Thirteenth lake. None were however observed in place, and this section is not very accessible.

Series 4. The small remnant of paleozoic strata near Wells furnishes the special point of interest in the local geology. The remnant presents the most complete section of any of the paleozoic outliers in the midst of the crystalline rocks. Several of these are now known, viz, near North River, Warren co.; near Putnam pond, Ticonderoga, Essex co.; Trout brook, near Lake George, Ticonderoga[1]; North Hudson, Essex co.; several in Crownpoint, Essex co.; and Schroon Lake postoffice, Schroon, Essex co. The last named is Calciferous, all the rest are Potsdam. There is excellent reason to think that another exists near Elizabethtown, Essex co., but only loose slabs of Potsdam have as yet been found. At Wells the Utica, Trenton, Calciferous and Potsdam beds have all been recognized, but the Chazy fails as is usual toward the south side of the mountains. The four strata present are each of very limited extent. The nearest outcrop of

[1] For a review of those in Ticonderoga, *see* Kemp, J. F. Physiography of the Eastern Adirondacks in the Cambrian and Ordovician periods. Bul. geol. soc. Amer. 8:408. *See also* 15th an. rep't N. Y. state geologist. 1895. p. 596. The North River, North Hudson and Elizabethtown cases have not yet been described in print.

related paleozoics is at Northville, about 13 miles to the south, where the Potsdam appears, and near which the Calciferous is known. The Trenton is met about 5 miles still farther south, and the Utica a few miles beyond. This outlier is therefore not so isolated as the Schroon lake exposure, which is 15 miles west and 40 miles north of the nearest related outcrops; and the North River exposure is even more remote from its own kind.

The exposures at Wells were first recorded by Ebenezer Emmons, so far as the writer (J. F. K.) can discover. In the *Geology of the second district*, p. 417, he says, while speaking of Hamilton county: "At Hope I found a few acres of Trenton rock, loaded with the usual fossils; and to the south a few miles, the Calciferous, each in place. They form the extreme point of the Champlain group, which comes up from the Mohawk valley through Northampton and Mayfield." Though Prof. Emmons said Hope, he must have meant Wells, as no outcrops occur at Hope. Prof. Hall has stated to the writer that Vanuxem first discovered the Wells exposures, in 1842, and this statement has been repeated by Darton, the writer, and Ruedemann, but Vanuxem's report on the third district makes no mention of the Wells outcrop, while Emmons does in 1842, as above quoted. Hamilton county belonged in the second district. Darton[1] gives some data regarding Wells and a geologic cross-section, which is however somewhat assumed, as a comparison with the detailed map here given will show. Mr Darton had the large faults in mind, that run north and south, and the details at Wells were somewhat incidental to a larger theme. Rudolf Ruedemann has also given considerable attention to the Wells area in connection with his extremely significant and interesting observations on the directions assumed by the graptolites in the Utica slates, which give a clue to the currents of the Ordovican sea.[2] Dr Ruedemann describes the Wells outlier as forming an oblong plain on whose sides the walls of gneiss rise

[1] Darton, N. H., 13th an. rep't N. Y. state geologist. 1893. p. 415. *Idem*. 1896. p. 47.

[2] Ruedemann, Rudolf. Evidence of current action in the Ordovician of New York. American geologist. June 1897. In this paper Wells or Wellstown, is merely referred to on the map. Additional note on the oceanic current in the Utica epoch. *Idem*. February 1898. p. 75.

in fault scarps, so that the valley is a depression dropped by faulting below the general level, i. e. it is one of the "Graben" as the term is used abroad. This appears to be certainly true for the west side of the valley, where the gneisses go up in a fairly steep wall, but it is less evident, though quite probable, for the east side. Dr Ruedemann develops an argument against the conception set forth by the writer in the "Physiography of the Adirondacks in the Cambrian and Ordovician periods" (cited above), that the early paleozoic sediments set up into embayments and submerged valleys in the subsiding archaean land area. The argument is based on the general similarity of the paleozoic beds at Wells to those of the main areas along the south side of the mountains; and on the general parallelism of the positions of the Wells graptolites as they lie in the slates, to those in the Utica beds to the south. Dr Ruedemann therefore infers a general mantle of the paleozoics over the crystallines and their preservation in this outlier by infaulting. As preliminary to farther discussion of this point, details of the Wells exposures will now be given.

Potsdam sandstone. The Potsdam appears in largest exposure just east of the Catholic church, but it is also revealed in a pit, about 8 to 10 feet deep, immediately east of the hotel. At the former locality 6 feet of thickness is exposed, but more lies below, so that a total of at least 30 to 35 feet was inferred. The rock is a fine grained, cream colored sandstone, rather thickly bedded, and shows occasional tendencies toward conglomerate. Ripple-marks are present. Under the microscope it appears as a quite pure quartz sand, with grains about $\frac{1}{50}$ of an inch in diameter (.5 mm). The grains are all rounded in a very noticeable degree, and they must have been well triturated before deposition. They are the common variety of quartz, as found in the ancient crystallines. A little kaolinized and somewhat iron-stained feldspathic material is also present.

The exposure back of the hotel is very limited in extent, and merely presents a fine, even grained and rather heavily bedded sandstone, of whose thickness we have no means of knowing. Its chief interest lies in the fact that it is flat and about 30′ below the

Calciferous limestone to the east, which doubtless rests on it, though the intervening connection is concealed by drift.

Calciferous. The Calciferous is exposed in only one place, which lies east of the hotel and stretches for some distance along the road leading northeast from the Roman catholic church. It is a non-fossiliferous, silicious limestone with nodules of white calcite. Cherty streaks were also observed. The limestone has a very slight inclination to the west. The thickness of the formation could not be determined, but in a brook valley, near its eastern limit, several feet were exposed, so that from the general relations a thickness of about 30 feet was estimated.

Under the microscope the limestone appears as a rather fine grained aggregate of dolomite crystals of about .01 of an inch (.2 mm) on the average, and quite richly set with rounded, waterworn grains of quartz, two or three times the diameter of the dolomites. In a slide from an outcrop about 100 rods east of the hotel the quartz grains make up one third the material. There are also round areas that suggest organisms, but no definite structure could be made out. Evidently the original of the dolomite, probably a limestone, was exposed to the sweep of rather swift currents and the incursion of moderately coarse sediment.

Trenton. The Trenton is in many respects the most interesting and significant of all the paleozoic exposures. It is a limestone that varies from light gray to almost black. It occurs in two places. The southern exposure, which lies on the west bank of the river, due west from the Catholic church, consists of loose boulders, which are not positively in place, but which are thought to be on the spot of the parent ledges. Comparatively little attention has therefore been given by us to this locality. The exposure of chief interest lies north of the Lake Pleasant (or Sageville) road and comprises a number of loose blocks and one large ledge that is certainly in place. The latter has received our special attention, and from it the material here noted was derived. The ledge is about 60 feet long, 30 feet wide, and 10 feet thick. Over the large blocks grassy hummocks of rectangular shape have

formed. The following section was measured in the large block above referred to. The strike is n 57 e, dip 7 w, true meridian.

No. 5 2 feet of rather thinly bedded, fine, black limestone, with abundant fossils.

No. 4 2 feet 6 inches of heavily bedded limestone rich in fossils. The grain is finer than no. 3, and abundant quartz grains occur through the rock.

No. 3 3 feet 6 inches of hard, coarse limestone, in 8 layers.

No. 2 6 inches to 14 inches of loosely textured, shattered limestone; white where weathered but dark inside; finely crystalline.

No. 1 1 foot hard limestone with abundant brachiopods, but not well preserved.

A number of fossils have been gathered from these ledges, which have been kindly determined for us by Gilbert Van Ingen, as follows:

No. 5 Hormospira alexandra *Billings*
Illaenus *sp.*
Cyrtoceras
Orthoceras *cf.* trochleare *Hall*, 1847
Strophomena incurvata *Shepard*
Crinoid, columnar plates

No. 4 Fragmentary fossils abundant but not adapted to sharp determination. Crinoid stems, brachiopods, trilobites and corals all recognizable. Illaenus sp. was the only one generically recognized. This layer also contains sand and pebbles of quartzite and gneiss, up to 3 to 4 inches in diameter, to which reference will be made below.

No. 3 This is the most productive layer, and its fossils are well preserved.

Strophomena incurvata *Shepard*
Plectambonites sericeus *Sowerby*
Isotetus gigas *Dekay*
Dalmanella testudinaria *Dalman*
Ceraurus pleurexanthemus *Green*

Rhynchotrema inequivalve *Castelnaw*
Parastrophia hemiplicata *Hall*
Hormospira alexandra *Billings*
Liospira americana *Billings*
Murchisonia ??
Sponge

No. 2 Strophomena incurvata *Shepard*
Parastrophia hemiplicata *Hall*

No. 1 Strophomena incurvata *Shepard*

Mr Van Ingen regards the fauna as being that of the lower part of the Trenton as found in the Champlain valley.

Layer no. 4 is a most remarkable rock, being a limestone but containing large quantities of quartz sand, and in places large pebbles of the old crystallines. The sand under the microscope is mostly well rounded and abraded, but some grains are angular. A little plagioclase feldspar is present, and one zircon was detected. In size the fragments range from .1 mm up to 15 mm (.004 to .5 inches). Definite iron-bearing silicates are lacking, but one magnetite fragment was observed. Thin sections were cut of two pebbles of the crystalline rock. Each was found to contain quartz and kaolinized microperthite in about equal amounts, and to have many pyrites disseminated through it. The pyrite was in part altered to limonite. The pebbles were certainly derived from the ancient crystallines and are pyritous quartzites or gneisses such as accompany the crystalline limestones. One pebble of a very fine limestone was also examined microscopically, but showed nothing unusual.

Utica slate. The Utica appears in three small separate exposures, lying on the west side of the river. The northern one is the largest and best, being 100 feet long, and 13 feet thick. The slaty cleavage strikes n 52 e, 15 n w, referred to the true north. Bedding is not apparent. In the two southern localities only a foot or two of weathered slate was exposed. The large outcrop was divided into five sections, of which the upper was 3 feet, the other four 2 feet each, and the fossils from each were

kept separate. They have been identified as follows by Mr Van Ingen:

No. 5 3 feet. Ostracoda, abundant
Turrilepas canadensis *Woodward*

No. 4 2 feet. Lamellibranch

No. 3 2 feet. Small Ostracoda in abundance

No. 2 2 feet. Calymmene senaria *Conrad*

No. 1. Indistinct Lamellibranch
Calymmene senaria *Conrad*

No graptolites were found by us, but Dr Ruedemann mentions Diplograptus foliaceus Murch. (=pristis Hall) and also fragments of Endoceras, and casts probably of Modiolopsis. He regards the rock as lower Utica.

The dips of all the beds are so low as to be with difficulty determined. A reading for the Potsdam was obtained of 3° to 4°n. The Calciferous dips slightly to the west. The Trenton strikes n 57 e and dips 7 n w when corrected for magnetic variation. In the Utica a supposed cleavage gave a reading n 52 e, 15 n w. It is evident from this that the dips are to the northwest, and that with the faulting there has been a slight tilting in this direction. At the same time it is surprisingly small, and the blocks must have dropped very easily. It is a speculative question as to whether the several blocks of paleozoics are themselves faulted with regard to each other. They either are, which we doubt, or else the cross-section of each is very small, and we must infer that the several formations have thinned greatly in this area, from their normal magnitude. The uncertainty of these relations is the reason for not drawing a cross-section.

In the interpretation of the deposits, the presence of the limestones would indicate that the estuary if present, in accordance with the views advanced for the Champlain side, must have been a very broad one; and we are quite free to admit that the present walls of the valley are fault-scarps. There is no question of this; but that a land area existed to the north and at no great distance, we think is equally assured. The Potsdam is a shore deposit, and

its characters indicate a beach sand. The Calciferous, though a limestone, must have been within reach of relatively swift currents charged with moderately coarse sand. The sand is general throughout the bed that contains it and is not in layers. It was afforded with some uniformity. In the Trenton times conditions evidently varied. Up through layer 3, sedimentation quietly and uniformly progressed, but at the time layer 4 was deposited there was an influx of sand and water-worn pebbles of large size, which are now mixed with rounded fragments of fossils and limestone. The sand is quite uniformly distributed through the rock, for some thickness. The pebbles and the sand were derived from the neighboring crystallines, and may have been mixed up with the lime by floating ice. The fact that the pebbles are of gneiss materially modifies the conclusions of Dr Ruedemann as set forth on page 78 of his paper (*Amer. geol.* 1898) in the discussion on the conglomerates in the Trenton, for he only knew of limestone pebbles at the time. They appear to us to demonstrate neighboring land areas of the archaean. While therefore the paleozoic sea evidently encroached on the ancient crystalline area, and may indeed at one stage have gone entirely over it, yet in the Trenton it did not cover it, and it is reasonable to suppose that, as the sea encroached in the Potsdam and Ordovician times, it set up estuaries. It is, however, certain that the walls of the Sacandaga valley are not the boundaries of the ancient estuary, if such existed.

Series 6. The glacial deposits are widespread in the town. On the hills they are morainal, and often contain large boulders. Gneiss, gabbro and anorthosite are the chief rocks present. In the valleys, water-sorted sands and gravels are the rule and near Wells the latter form pronounced terraces. Near specimen 178, to the southwest of Wells village, glacial striae were observed on the hornblendic gneiss which there outcrops. Their direction is n 40 e magnetic, or n 52 e when referred to the true north. This corresponds with the general experience in eastern Hamilton county. Boulders of Potsdam were noted near by.

Lake Pleasant

Topography. Lake Pleasant is a long and relatively narrow township, lying north and west from Wells, and southwest from Indian Lake. It is one of the largest townships in the county, being some 25 miles from north to south and about 8 miles from east to west. The southern third of the town is largely occupied by a broad valley containing Lake Pleasant, Sacandaga lake, Fawn lake, Hamilton lake, and running westward into Arietta township, with Oxbow lake on the border and Piseco lake just over the line. In this valley most of the population is located. The village of Lake Pleasant is the county seat, and Speculator, formerly called Newton Corners, is another hamlet. Each contain a few hundred people, but are popular resorts during the summer months. Fawn, Oxbow and Piseco lakes drain off to the southwest into the west branch of the Sacandaga, while Lake Pleasant and Sacandaga lake discharge to the north into the Jessup river and so out to Indian lake and the Indian river.

The general elevation of this portion is moderate, ranging about 1700 feet A. T., and the hills are of comparatively slight altitude. Speculator mountain on the east side of Lake Pleasant attains 2500 feet and is the most prominent summit of all. It is quite possible that the open character of this area is in part due to the presence of crystalline limestones, of which we have found considerable outcrops.

As one goes north, however, the country becomes more rugged, and the higher summits attain notable altitudes. Dry mountain, in the central part of the town, is 3260 feet above tide, and other neighboring peaks are but little less. Still farther north the mountains reach higher levels. The Blue Ridge is 3865; Lewey, 3740; Cedar, 3402; two unnamed peaks attain 3723 and 3685, as shown by the Indian Lake sheet of the United States geological survey. All these peaks lie along large ridges, whose trend is markedly northeast and southwest, and the lakes and streams likewise have this general direction. As a rule the ridges are separated by narrow valleys but in the case of the Lewey lake—Indian lake depression and the Cedar river flow,

they are broader and more pronounced. Lewey lake is 1651 above tide and the Cedar river is 2100.

Our explorations have been chiefly limited to the southern and central parts of the township. The extreme northwest has not been visited, but, aside from possible limestone and gabbro areas, there is every reason to expect the usual gneissoid rocks. No recorded work has been dône very near this point to the west, but the gneisses met by Prof. C. H. Smyth jr at Honnedaga lake and the gneisses with gabbros near Wilmurt lake would give ground for expecting these types.

Series 1. The gneisses are much the most important rocks in the township, and they present among themselves considerable variety. In the field the greater part was collected as hornblendic gneiss. No. 158 has, for example, the aspect of a reddish, hornblendic granite. Nos. 157 and 159 are greatly squeezed, hornblendic varieties, rusty on exposure, but darker and darker green as one breaks into the fresh interior. They show comparatively little quartz to the eye, but appear to be rather syenitic in their composition. No. 150 is a dark green and apparently somewhat basic rock, but, when it is examined under the microscope, abundant quartz is seen. The other minerals are orthoclase, plagioclase, colorless augite, brown hornblende, and feebly pleochroic, orthorhombic pyroxene. It is a pyroxene-granite and is very badly crushed and sheared. No. 156 is the same variety of rock as 163a. No. 162 appears to be a very finely crushed pegmatite or haplite, if indeed it is not a metamorphosed feldspathic sandstone. Dark silicates are very few, though some scales of muscovite are visible. No. 164 is a greatly crushed and granulated aggregate of quartz, microperthite, plagioclase, orthoclase, and biotite. No. 165 is a fairly massive, hornblende granite or related rock.

So far as examined with the microscope, all these rocks show the effects of severe crushing and have evidently undergone extensive dynamic metamorphism. Foliation is never lacking, though in some it is more pronounced than in others. The strike of the foliation is somewhat variable, but it is rather more often

northwest than otherwise. This trend is pronounced in the northern part of the township. In the southern part, near and west of Speculator and near the limestone areas, it is quite variable. The dips are prevailingly southwest and as a rule are flat. But many cases of uncertain dips arise, and in these no record could be obtained.

Series 2. Two areas of crystalline limestones and associated rocks have been met. The larger begins a short distance northwest of Speculator and extends 2 miles along the road to Lewey lake. It involves outcrops of crystalline limestone and the peculiar types of rock that are often associated with it. No. 154 is limestone, with a little coccolite and some graphite. It appears in a ledge with pyroxenic rock, and varieties resembling quartzites. The limestone extends about half a mile along the highway to the northwest and changes gradually into a more and more silicious variety, which finally becomes a rusty rock represented by no. 155. Under the microscope it is found to be chiefly a clear, colorless pyroxene, with scales of graphite and irregular bits of pyrrhotite and titanite. This pyroxene is a rather characteristic associate of the limestones, and will be mentioned again in connection with 153. Specimen 152 is a green rock full of pyrrhotite. In connection with the varieties mentioned there is also a notable development of pegmatites, such as are habitually seen near the limestone areas. Bands of pyrrhotite-gneiss like 152 appear quite frequently, and, while the usual gneisses are present, the former leave a strong impression of being metamorphosed sediments. These peculiar rocks, characteristic of the limestone series, also extend along the road to Whittaker (or Wallula) lake, and they may cover more area than we give them on the map.

The second exposure was found along the road northeast from Speculator toward Elm lake. Only small outcrops of limestones were seen, but specimen 153 is a graphitic, gneissoid rock, or quartzite, and would therefore appear also to belong to this series. Under the microscope it exhibits quartz, colorless pyroxene, yellowish phlogopite, zircons and graphite. Apparently it must have been a somewhat calcareous sandstone or shale before meta-

morphism and must have contained some bituminous matter which yielded the graphite.

In the large area of series 2, the strike so far as recorded is northeast, but at opposite ends of the exposures the dips are opposed to each other. We have, however, too few data at hand to justify conclusions as to structure. Contrary to the usual experience this area of the limestone series is on the hills instead of being in the valleys.

Series 3, 4 and 5. No anorthosites or gabbros, no paleozoic strata and no trap dikes have thus far been discovered.

Series 6. Glacial sands and gravels are found in heavy deposits throughout the Lake Pleasant valley, but are thin or wanting on the higher elevations to the north. Glacial striae were found northeast of Speculator, with a northeasterly bearing, just as in Wells.

Indian Lake

The northern part of Indian Lake was covered in our report for 1897. The southern part is alone taken up at this time.

Topography. The southern part of Indian Lake township consists of three pronounced northeast and southwest ridges with two deeply incised valleys between them. In the southeastern one lies Indian lake, about 7 miles in length—with a maximum width of half a mile. This is the size recently produced by raising the old dam that formerly existed at its lower end, so that an old overflow was included in the lake. It is planned to raise it still farther, so that it will set back into Lewey lake. The present altitude of Indian lake is 1626. From its shores the mountains rise steeply, reaching on the east about 2500 feet as a maximum, but on the west, in Snowy mountain, a maximum of 3903. The valley of Squaw brook, a steep and narrow depression, then intervenes, and on its western sides the peaks range from 3500 to almost 4000 feet. All this part is wild and not easily accessible. Snowy mountain is the highest in the Adirondacks outside of Essex and Franklin counties.

Indian Lake township is very sparsely settled. A few houses are found along the highway from North creek to Blue mountain

lake, which latter is a popular summer resort, but aside from this the town is practically a wilderness. The geologic exploration is still quite fragmentary, but, adding to last year's report the observations of 1898, a general idea may be formed of its leading features. The present notes are chiefly based on a trip from Lewey lake through Indian lake, with detours into the mountains lying on each side.

Series 1. Gneisses make up almost the entire area. Last season's work showed that a quartz-hornblende variety was the chief one in the northern part of the area. The 1898 work has brought to light in specimens 160 and 161 gneisses like 150 of Lake Pleasant. They have the mineralogic composition of pyroxene-granite. They are strongly foliated and present glistening cleavage faces on the feldspars that are characteristic of this variety of rock.

A strike in each of these cases was noted, bearing to the northwest, which is impressive because it crosses the trend of the ranges. The dip was low to the south.

Series 2. A small area of crystalline limestones and associated rocks was noted in last year's report from the eastern town line, on the North creek road.

Series 3, 4 and 5. No gabbros, anorthosites, paleozoics or trap dikes have as yet been discovered.

Series 6. The glacial deposits surround Indian lake and are present in the valleys and on the broader or lower hills. The higher summits are, however, quite bare. Glacial striae noted in 1897 near Blue mountain lake bear a little east of north and are therefore more northerly than those of Lake Pleasant and Wells.

Warren county

Johnsburg

Topography. Johnsburg is the largest township of Warren county and lies in its extreme northwestern corner. Over the greater part of the area the township is very sparsely settled, the farms occurring chiefly along or near the Hudson river, or on the highway which runs across the southwestern corner to Wells in Hamilton county, and which passes through the hamlets of

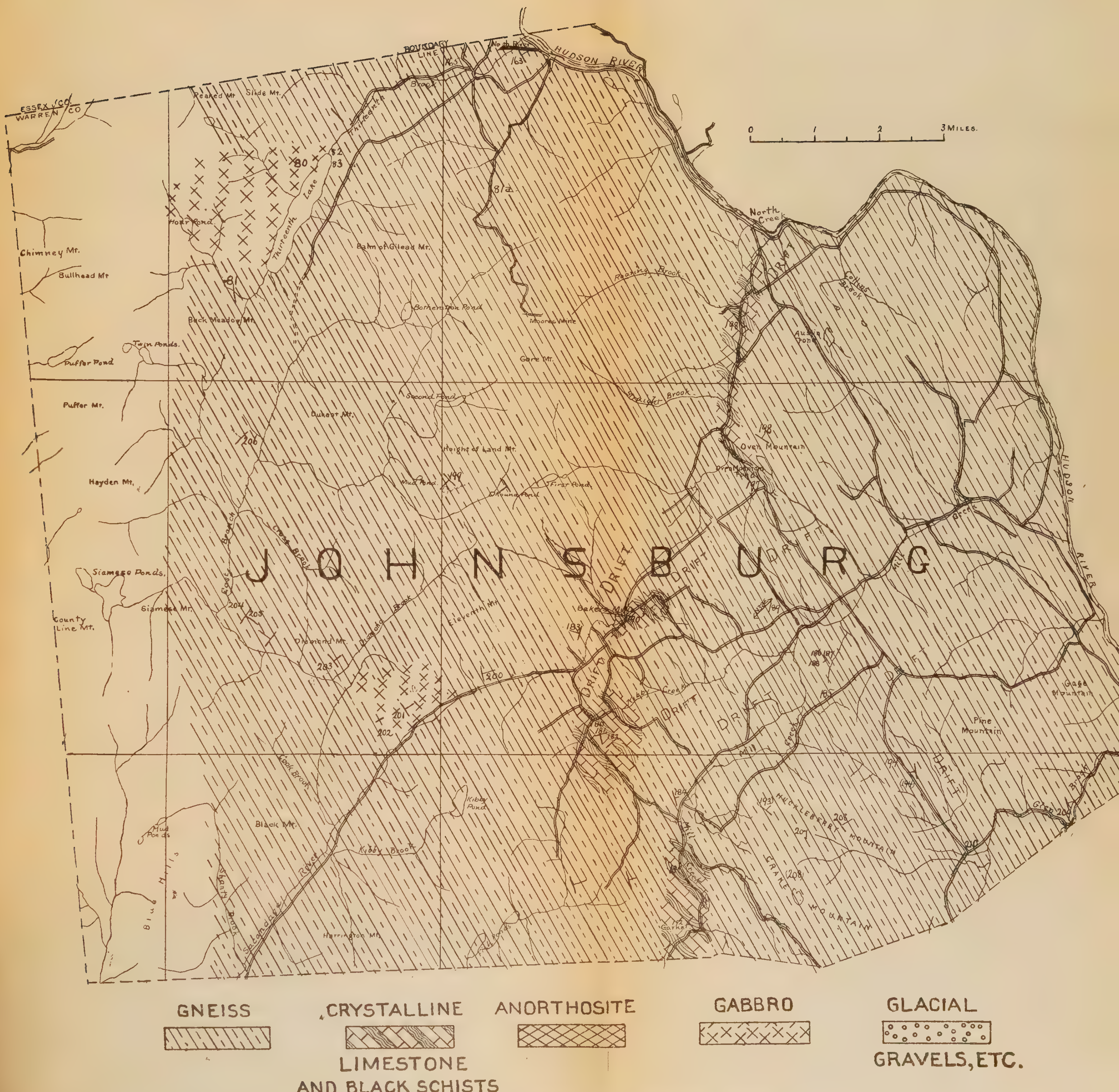
Bakers Mills and Oregon. Johnsburg village lies about three miles west of the Hudson in the eastern central part of the town. Northcreek, the present terminus of the Adirondack railway, and North River, 5 miles up stream, are in the extreme northeast corner. Several small villages are also situated in the eastern part.

The Hudson forms the eastern boundary and flows in a valley, which is shut in by low hills. Passing westward across Johnsburg, one meets with hills of moderate elevation and of rather easy slopes, except for Huckleberry and Crane mountains on the south, respectively 2441 and 3245 feet above tide, and Gore mountain on the north, a huge mass, 3594 feet high. In the southwest the topography becomes again extremely rugged. The Sacandaga river and its tributary, the east branch, have cut their way through narrow passes in this portion, and, though the latter rises on the west slopes of Gore mountain, within 5 miles of the Hudson, its waters flow more than 50 miles before they enter it. In the southwest the mountains almost reach 3000 feet, the Blue hills attaining 2938, but farther north and nearly in the middle of the town Eleventh mountain is 3303. The northwest corner of the town is also very rugged and mountainous, Puffer mountain being 3480 and Bullhead 3455. In a narrow valley lies Thirteenth lake, a fine body of water, 2 miles long and 1674 feet above tide. All the drainage of the township passes into the Hudson, though the streams in the southwestern part do so through the Sacandaga by a very circuitous course.

Geology. Much the greater part of the town consists of the gneisses of series 1. The crystalline limestones are however present in important exposures, which throw much light on their general stratigraphic relations. The anorthosites and gabbros have also been found in quite extended areas, and one small but interesting outlier of Potsdam has been discovered in the northeastern portion. Trap dikes have not been noted, but the glacial deposits and their attendant terraces are very widespread.

Series 1. The gneisses present exposures which do not yield in point of interest to any other areas in the Adirondacks. They

Plate 3



GEOLOGIC MAP OF JOHNSBURG, WARREN CO.

deserve much more detailed study than we have been able to give them, and, when this has been done, the genetic and structural problems can no doubt be pushed well along toward solution. The gneisses embrace some varieties that are certainly altered sediments. The latter are thinly schistose, richly micaceous and often abundantly provided with quartz. They exhibit in many exposures marked evidence of severe dynamic metamorphism, and have evidently been subjected to extremely powerful compression. When broken parallel with the schistosity, they show the small surfaces along which individual lenses have slipped and rubbed. Results like these are characteristic of deformation in the zone of fracture and under comparatively small load—according to the phraseology and conceptions established by Van Hise.

Other varieties of gneisses are more massive and seem to have suffered less granulation. They present varieties consisting of quartz, hornblende orthoclase and plagioclase and are less certainly derived from sediments. In a number of exposures appears the coarse variety with the large lenses of quartz in the midst of microperthite, which has been met in the northern Adirondacks, particularly by Prof. Cushing near Franklin Falls, Franklin co. This variety of rock is probably an altered conglomerate.

In the vicinity of the crystalline limestones, quartzites or quartzose gneisses appear which are beyond question metamorphosed sandstones, and which will be referred to under series 2.

We have also met a few exposures of the dark green gneisses, which are regarded as metamorphosed augite syenites, such as were referred to in our last report as the "Whitehall type." The exposures, so far as observations go, are not specially numerous, but additional fieldwork may disclose more of them.

The western line of the town is not easily reached without camping, a mode of operation which we have been unable to adopt, but there is little doubt from our observations in Hamilton county, as shown by the maps elsewhere printed in this report, that the gneisses cover practically all this portion. There may be however, specially on the northeast, developments of anortho-

site, as we are uncertain how far the area there partially colored may extend.

The prevailing strikes of the gneisses are northeast and northwest. The dip is more often to the east than to the west, though some western ones have been recorded. These relations are probably due in part at least to faulted blocks, whose steep escarpments look off to the westward. The drainage lines are in most cases either northeast and southwest or northwest and southeast, following great structural breaks along these directions.

Hornblende schists or amphibolites are occasionally present in the areas colored as gneiss, and in one or two cases either in the township or just across its northern boundary they contain very coarse crystals or crystalline masses of garnet. The garnet has proved of economic value as an abrasive and is mined, crushed, sized and marketed. Moore's mine, on Gore mountain, is one locality, and the North River garnet co.'s mine just north of the boundary of the township is another.

Series 2. The limestones and their associated beds are found in four separated areas, as drawn on the map, but, though the sign for gneiss appears between them, it is quite possible that under the concealing drift, they may be present instead of the gneiss. The typical limestones are coarsely crystalline varieties, almost always containing disseminated serpentine. They seldom reach more than a few feet in thickness, and are interbedded with quartzites, thinly schistose gneisses, hornblende schists and granular, pyroxenic aggregates. Scapolite rocks seem likewise to be present.

In addition to the areas mapped there is a small bed of limestone in the ledges west of the town of North River, a continuation or associate of the much larger exposures on the east bank of the Hudson in Chester.

Graphite is quite commonly present in the limestones and is somewhat richly disseminated in some of the quartzites associated with them. In one or two instances it has attracted some attention from prospectors.

Series 3. The anorthosites have been discovered by Mr Newland in two localities. One is on the west shore of Thirteenth

lake and extends for a considerable and as yet unknown distance to the westward. The principal rock present is a coarsely crystalline aggregate of labradorite with very little of the dark silicates present. There is evidence of crushing, but there has been slight if any development of gneissoid foliation. Specimens were collected near the outlet of Thirteenth lake which show sharp eruptive contacts against the gneiss. Gabbros of basic character likewise appear along the northern side of this area.

The second area lies to the south of the first and is near the road leading from Bakers Mills to Wellstown. The anorthosite is rather strongly gneissoid and has been more sheared than in the northern locality. Mr Newland observed however a good eruptive contact against the gneiss.

The exposures of the anorthosites are the most southerly of those yet discovered in the eastern mountains, and probably mark the limits of the formation in this direction. In statements of this character, mention should however also be made of the augite syenite gneisses, which may belong with the anorthosites in their geologic relations and which were referred to under series 1.

Series 4. Along the brook that heads to the westward from North River and about 2 miles from the village numbers of large boulders of Potsdam sandstone are found, giving every reason to think that they are not far from their parent ledges. There is little doubt that there is an outlying area of the Potsdam at this point, and the discovery adds another to the remnants of this formation which have already been met, so far removed from the larger southern exposures.

Series 5. No trap dikes have been observed.

Series 6. The glacial deposits are widespread and important and should be a special object of study. Morainal material is widely distributed. Glacial scratches have been observed in only one instance, which was about 3 miles east of Bakers Mills. They bore n 32 e magnetic, or about n 20 e true.

Along the Hudson there is one remarkable terrace about 40 feet above the stream, and opposite the tributary streams are deltas in very striking development, but our observations are not yet sufficiently detailed to correlate them.

Washington county

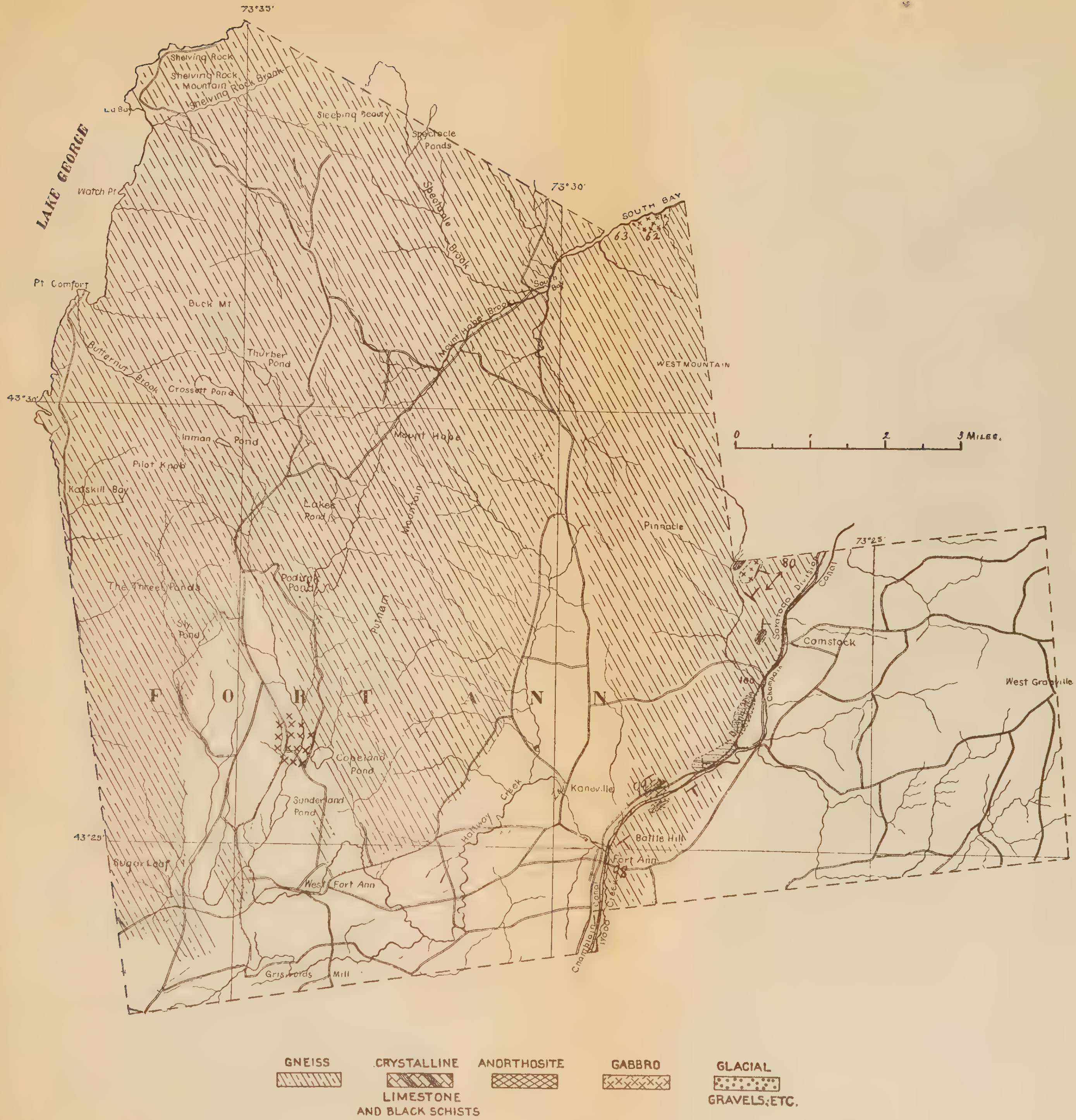
Fort Ann

In the report of the state museum for 1897, p. 529-32, a preliminary sketch of Fort Ann township is published together with a partial map. The topography and the drainage are there briefly described, and some notes on the petrography of the gneisses, crystalline limestones and gabbros of the eastern part of the crystalline area are given. In August 1898 Mr Hill spent several days in traversing the ridges in the central and western part of the township and as the results of his observations, the map has been extended as shown in the accompanying plate. The high ridge of Putnam mountain and the ridge connecting Pilot Knob with Sugar Loaf on the western limits of the town are all gneiss and apparently of the same general character as that already described from Pinnacle mountain. Basic hornblendic bands have been noted in a few instances. Also, near Mt Hope, sheared augite syenites of the "Whitehall type", as described in our last report, p. 507. Just west of Copeland pond gabbro has been discovered in two places, viz, one on each of the highways.

The boundaries of the gneisses as against the paleozoics have not been sharply delimited in the southwestern part of the township, partly because of the abundant drift and partly from insufficent observations. There is one outlier of the Cambro-Silurian strata that lies on the gneisses to the northwest of West Fort Ann. It is shown on the map prepared by Charles D. Walcott to accompany his paper on the "Taconic system of Emmons, etc." (*Amer. jour. of science.* April 1888. pl. 3), and on the large, geologic map of the state issued in 1894. While the crystallines are drawn on the map where Mr Hill has observed them, the observations are not sufficiently detailed to revise the details of the earlier map, and the latter is on a scale so much smaller that incorporation is unfeasible.

One iron mine of considerable size was formerly operated near Podunk pond.

Plate 4



GEOLOGIC MAP OF FORT ANN, WASHINGTON CO.

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The superior figures tell the exact place on the page in ninths; e. g. 108^3 means page 108, beginning in the third ninth of the page, i. e. about one third of the way down.